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QUATERNARY GEOLOGY OF THE CARMACKS MAP AREA, YUKON TERRITORY

L.E. Jackson, Jr.

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Lionel E. Jackson, Jr.

With appendices by Hélène Jette, Robert J. Mott, Charles Tarnocai, and Alice M. Telka.

2000

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Cover illustration

Ne Ch'e Ddhäwa, a 300 m high extinct volcano. It last erupted beneath a Cordilleran ice sheet during the youngest of the pre-Reid glaciations between about 0.8 and 1 million years ago. Photograph by L.E. Jackson, Jr. GSC 1999-012L

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CONTENTS

Illustrations

Figures

Tables

Appendices

QUATERNARY GEOLOGY OF THE CARMACKS MAP AREA, YUKON TERRITORY

Abstract

The Carmacks map area has been partly or extensively glaciated a minimum of four times during the past ca. 1.5 million years. The two oldest, named pre-Reid glaciations occurred prior to the last magnetic reversal (>0.78 Ma BP). The pre-Reid glaciations and subsequent Reid Glaciation were separated by at least two periods of interglacial climate. Interglacial climates were similar to those of today or radically warmer. The Wounded Moose paleosol developed early in this period. Auriferous placers were deposited in the Dawson Range. The glacial ice was less extensive during Reid Glaciation than during the pre-Reid glaciations. During the period between the Reid and McConnell glaciations, the climate warmed to one comparable to the present. The Diversion Creek paleosol developed during this mild interval. The glacial ice cover of the latest (McConnell) glaciation was less extensive than that of the Reid Glaciation. Following the end of the McConnell Glaciation, the Yukon River, and presumably other major streams, incised close to their contemporary levels by the early Holocene. Volcano Mountain erupted around the Pleistocene–Holocene boundary and may have been active during the mid-Holocene.

Bedrock is characteristically competent in the study area with the exception of the Carmacks Group. The most significant occurrences of placer gold occur in the Dawson Range. They result from the weathering and transport of lode gold associated with intrusions of the felsic subvolcanic Mount Nansen Group. All existing placer operations either overlie or are topographically downslope from Mount Nansen Group intrusions.

Résumé

La région cartographique de Carmacks a subi au moins quatre glaciations partielles ou de grande envergure au cours des quelque 1,5 million dernières années. Les deux glaciations nommées les plus anciennes qui sont antérieures à la Glaciation de Reid se sont produites avant la dernière inversion magnétique (>0,78 Ma). Ces deux glaciations et la Glaciation de Reid ont été séparées par au moins deux périodes de climat interglaciaire. Les climats interglaciaires étaient semblables à celui d'aujourd'hui ou beaucoup plus chauds. Le paléosol de Wounded Moose s'est formé au début de cette période. Des placers aurifères se sont accumulés dans le chaînon Dawson. Les glaces glaciaires étaient moins étendues au cours de la Glaciation de Reid que pendant les glaciations antérieures. Pendant l'intervalle entre les glaciations de Reid et de McConnell, le climat s'est réchauffé à des températures comparables à celles de notre époque. Le paléosol du ruisseau Diversion s'est constitué au cours de cet intervalle de climat doux. La couverture de glace de la glaciation la plus récente (McConnell) était moins étendue que celle de la Glaciation de Reid. Après la fin de la Glaciation de McConnell, le fleuve Yukon et vraisemblablement d'autres grands cours d'eau se sont encaissés, atteignant des niveaux presque comparables aux niveaux actuels dès l'Holocène inférieur. L'éruption du mont Volcano s'est produite vers la limite du Pléistocène et de l'Holocène; il se peut que le volcan ait été actif au cours de l'Holocène moyen.

À l'exception du Groupe de Carmacks, le substratum rocheux est typiquement compétent dans la région étudiée. Les placers aurifères les plus importants se rencontrent dans le chaînon Dawson. Ils sont le produit de l'altération et du transport d'or primaire associé à des intrusions du groupe felsique subvolcanique de Mount Nansen. Tous les placers actuellement en exploitation sont sus-jacents à ces intrusions ou sont topographiquement en pente descendante par rapport à celles-ci.

SUMMARY

The Carmacks map area has been partly or extensively glaciated four times during the past ca. 1.5 million years. The two oldest, named pre-Reid, occurred prior to the last magnetic reversal (>0.78 Ma BP). The Yukon River was flowing close to its contemporary level and in its contemporary direction at the start of the oldest known of these glaciations. Ice invaded the map area from the south and west and covered all but the highest ridges. The Dawson Range also supported cirque and valley glaciers. Eruption of valley-filling basaltic lava and hyaloclastite accompanied the younger of the pre-Reid glaciations in the Fort Selkirk area. The pre-Reid glaciations were separated by at least one period of interglacial climate. Sediments from this interval have yielded remains of large and small mammals. Deposits of the pre-Reid glaciations are largely buried beneath colluvium or loess. Large meltwater channels are the only geomorphic features that survived from these glaciations.

The pedological and paleoenvironmental evidence from a core through sediments filling a pre-Reid meltwater channel near Pony Creek in the Dawson Range indicates that climate fluctuated, from glacial to one similar to that of the present or radically warmer and wetter, at least twice during the interval between the last pre-Reid glaciation and the Reid Glaciation (much of the mid-Pleistocene). The Wounded Moose paleosol developed early in this period and the auriferous placers of the Dawson Range formed during this period.

Glacial ice was less extensive during the Reid Glaciation than it was during the pre-Reid events. Ice occupied the eastern half of the map area and advanced down the Yukon River as far as Fort Selkirk. Glacial landforms contemporaneous with Reid Glaciation are subdued and eroded compared with those of the younger McConnell Glaciation. In many areas loess formed during the McConnell Glaciation obscures the Reid landforms and makes the identification of the limits of Reid ice cover difficult. The latest (McConnell) glaciation was the least extensive with the digitate margin of the Cordilleran Ice Sheet extending down valleys and covering low uplands only in parts of the eastern third of the map area. McConnell landforms are sharp crested and lakes are plentiful within the McConnell Glaciation limit in contrast to Reid Glaciation terrain. The climate warmed to that comparable to the present or warmer for at least part of the time between the Reid and McConnell glaciations based on paleoenvironmental evidence from Revenue Creek. The Diversion Creek paleosol developed during this mild interval.

SOMMAIRE

La région cartographique de Carmacks a subi quatre glaciations partielles ou de grande envergure au cours des 1,5 million dernières années. Les deux glaciations nommées les plus anciennes qui sont antérieures à la Glaciation de Reid ont eu lieu avant la dernière inversion magnétique (>0,78 Ma). Au début de la plus ancienne connue de ces glaciations, la direction du courant et le niveau du fleuve Yukon étaient à peu près les mêmes qu'aujourd'hui. Les glaces ont envahi la région cartographique à partir du sud et de l'ouest et ont recouvert entièrement la région à l'exception des crêtes les plus élevées. Le chaînon Dawson a également été le siège de glaciers de cirque et de vallée. Dans la région de Fort Selkirk, la formation de hyaloclastites et l'éruption de laves basaltiques qui ont comblé les vallées ont eu lieu en même temps que la plus récente des glaciations antérieures à la Glaciation de Reid. Ces glaciations ont été séparées par au moins une période de climat interglaciaire. Les sédiments accumulés au cours de cette période renferment des vestiges de petits et de gros mammifères. Les dépôts des glaciations antérieures à la Glaciation de Reid sont pour la plupart ensevelis sous des colluvions ou du loess. De vastes chenaux d'eau de fonte constituent les seuls éléments géomorphologiques qui ont survécu à ces glaciations.

Une carotte qui a traversé des sédiments remplissant un chenal d'eau de fonte d'une glaciation antérieure à la glaciation de Reid, prélevée à proximité du ruisseau Pony dans le chaînon Dawson, a fourni des données pédologiques et paléoenvironnementales qui montrent que les conditions climatiques ont fluctué dans cette région, passant d'un climat glaciaire à un climat similaire à celui de la période actuelle ou même radicalement plus chaud et plus humide. Ces fluctuations se sont produites au moins à deux reprises au cours de l'intervalle qui a séparé la dernière glaciation antérieure à la Glaciation de Reid et la Glaciation de Reid (une grande partie du Pléistocène moyen). Le paléosol de Wounded Moose s'est constitué tôt au cours de cette période et les placers aurifères du chaînon Dawson se sont formés également durant ce même intervalle.

Les glaces glaciaires étaient moins répandues au cours de la Glaciation de Reid que pendant les glaciations antérieures. Elles occupaient la moitié orientale de la région cartographique et se sont avancées le long du fleuve Yukon jusqu'à la hauteur de Fort Selkirk. Les modelés glaciaires contemporains de la Glaciation de Reid sont plus adoucis et érodés que ceux de la glaciation plus récente de McConnell. Dans de nombreuses régions, des dépôts de loess qui se sont formés au cours de la Glaciation de McConnell masquent les modelés de la Glaciation de Reid, ce qui complique la délimitation de la couverture glaciaire de la Glaciation de Reid. La dernière glaciation (McConnell) a été la moins étendue, la marge digitée de l'Inlandsis de la Cordillère ayant descendu les vallées et recouvert les hautes terres uniquement dans des parties du tiers oriental de la région cartographique. Dans la région touchée par la Glaciation de McConnell, les sommets des modelés sont aigus et les lacs sont nombreux, ce qui contraste avec le terrain touché par la Glaciation de Reid. D'après les données paléoenvironnementales provenant du ruisseau Revenue, le climat s'est réchauffé et était comparable au climat actuel ou même plus chaud pendant au moins un certain temps entre les glaciations de Reid et de McConnell. Le paléosol du ruisseau Diversion s'est constitué au cours de cet intervalle plus clément.

The Yukon River, and presumably other major streams, eroded close to their contemporary levels by the early Holocene. Volcano Mountain erupted near to the Pleistocene–Holocene boundary and may have also erupted during the mid-Holocene.

Bedrock is characteristically competent in the study area. The one remarkable exception is the Carmacks Group which is highly prone to failure as complex landslides. Failures may be many square kilometres in size and consequently are difficult to recognize on the basis of individual large-scale airphotos. Foundation conditions in surficial deposits vary largely with permafrost conditions.

The seismological network of the Geological Survey of Canada has had the capacity to detect earthquakes as low as magnitude 4 within the Carmacks map area since 1978 and magnitude 2 since 1984. All recorded earthquakes within and immediately adjacent to the study area have been less than magnitude 5 since 1978. Volcanic activity last occurred within the Carmacks map area at Volcano Mountain during the early Holocene or late Pleistocene. Renewed volcanism in that area, should it occur, would likely be accompanied by local earthquake activity.

Floods due to ice-jamming during spring break-up, snow melt, and summer rainstorms are potential hazards along streams throughout the study area. Alluvial fans are also flood hazard areas. They are subject to both inundation with floodwaters and stream avulsion with the added hazard of inundation by debris flows on steeper fans.

The occurrence of placer gold in this region results from the congruence of gold-bearing Cretaceous granite and granodiorite units and their subvolcanic equivalent, the Mount Nansen Group, with a favourable weathering and glacial history. All existing placer operations either overlie or are topographically downslope from these bedrock units or mineralized zones where these rocks contact country rock. The factors that led to the deposition of known gold placers in the Nansen–Big Creek placer district should also have been coincident elsewhere in the Dawson Range and should be a guide for future exploration.

Le fleuve Yukon et vraisemblablement d'autres grands cours d'eau se sont encaissés, atteignant des niveaux presque comparables aux niveaux actuels dès l'Holocène inférieur. Le mont Volcano a fait éruption à la limite du Pléistocène et de l'Holocène et peut-être aussi au cours de l'Holocène moyen.

Le substratum rocheux est typiquement compétent dans la région à l'étude. Il existe néanmoins une exception notoire, soit le Groupe de Carmacks, qui est fortement enclin à la rupture sous forme de glissements de terrain complexes. Ces ruptures peuvent couvrir nombreux kilomètres carrés et sont donc difficiles à reconnaître sur des photographies aériennes à grande échelle. Les conditions du sous-sol dans les dépôts superficiels varient largement en fonction des conditions du pergélisol.

Depuis 1978, le réseau sismologique de la Commission géologique du Canada a les capacités de détecter des séismes de magnitude aussi faible que 4 et, depuis 1984, même de 2, dans la région cartographique de Carmacks. Depuis 1978, tous les séismes enregistrés dans la région étudiée ou tout près sont de magnitude inférieure à 5. Dans la région cartographique de Carmacks, la dernière phase d'activité volcanique a eu lieu au mont Volcano au cours de l'Holocène inférieur ou du Pléistocène supérieur. Si le volcanisme se ravivait dans cette région, il serait vraisemblablement accompagné de séismes locaux.

Des inondations provoquées par les embâcles au cours des débâcles printanières, par la fonte des neiges et par les pluies d'orages en été constituent des risques potentiels le long des cours d'eau dans l'ensemble de la région étudiée. Les cônes alluviaux sont également des zones potentiellement inondables. Elles sont sujettes à la fois aux inondations accompagnées de décrues et à l'avulsion, ainsi qu'aux inondations par des coulées de débris sur les cônes les plus abrupts.

La formation d'or placérien dans cette région est attribuable à la présence d'unités de granite et de granodiorite aurifères crétacés et de leur équivalent subvolcanique, le Groupe de Mount Nansen, ainsi qu'à une histoire favorable de glaciation et d'altération. Tous les placers actuellement en exploitation sont sus-jacents à ces unités du substratum rocheux ou à ces zones minéralisées à l'endroit où ces roches sont en contact avec la roche encaissante ou sont topographiquement en pente descendante par rapport à ces unités ou à ces zones minéralisées. Les facteurs qui ont entraîné l'accumulation de placers aurifères connus dans le district placérien de Nansen–Big Creek devraient également être présents ailleurs dans le chaînon Dawson et pourraient servir de guide à de futurs travaux d'exploration.

INTRODUCTION

The Quaternary geology of the Carmacks map area has long been of considerable scientific and economic interest. The first remains of ice age megafauna discovered in Yukon Territory were collected here in the middle of the last century by the Hudson Bay Company merchant explorer Robert Campbell. Campbell's post diary from Fort Selkirk extends earthquake records to the same period (Jackson, 1990). A record of multiple glaciation and Quaternary volcanism was discerned by H.S. Bostock in the 1920s and 1930s. Placer gold was discovered in the map area not long after the great Klondike gold discoveries of 1896. However, the details of the glacial history of this area and the age and stratigraphic context of placer deposits has only recently been studied in detail (Hughes, 1990; Jackson, 1993; LeBarge, 1995) and remains incomplete. This report details an investigation of the surficial geology of the Carmacks map area carried out by the author as a part of larger effort to map the surficial geology of eastern and central Yukon Territory. This effort is part of a larger regional mapping project which mapped the surficial geology across Yukon Territory from the Northwest

Territories boundary to the Carmacks map area under the direction of the author. This effort has resulted in a better understanding of the glacial history of the region including the direction of ice flow and the nature of the drift cover. These aid in the exploration for mineral resources as well as planning activities and evaluation of landscape sensitivity. Mapping of the surficial geology of the Carmacks map area is the culmination of this effort (*see* maps 1976A, 1977A, 1978A, 1979A, in pocket). It represents the first concerted effort to systematically understand the Quaternary history of this fascinating area from the end of the Tertiary Period to the Holocene Epoch (the present nonglacial period).

PHYSIOGRAPHIC SETTING

The Carmacks map area lies entirely within the "Yukon Plateaus" (Mathews, 1986), a rolling upland with broad and generally accordant summits and ridges that typically lie below 1500 m a.s.l. (Fig. 1, 2) although isolated peaks in the Dawson Range such as Tritop Peak, Victoria Mountain, and Klaza Mountain rise to more than 1820 m. This upland surface has escaped glaciation entirely or has experienced only incipient alpine glaciation based upon scattered incised cirque-like features near the summits of some of the highest peaks such as Prospector Mountain and Mount Nansen. The most accordant summits are underlain by the Late Cretaceous Carmacks Group basalts (Grond et al., 1984). These were erupted over an eroded surface with local relief of up to 700 m (Tempelman-Kluit, 1980). The presence of these formerly valley-filling volcanic rocks underlying contemporary ridge tops indicates the significant erosion and topographic inversion since the late Cretaceous.

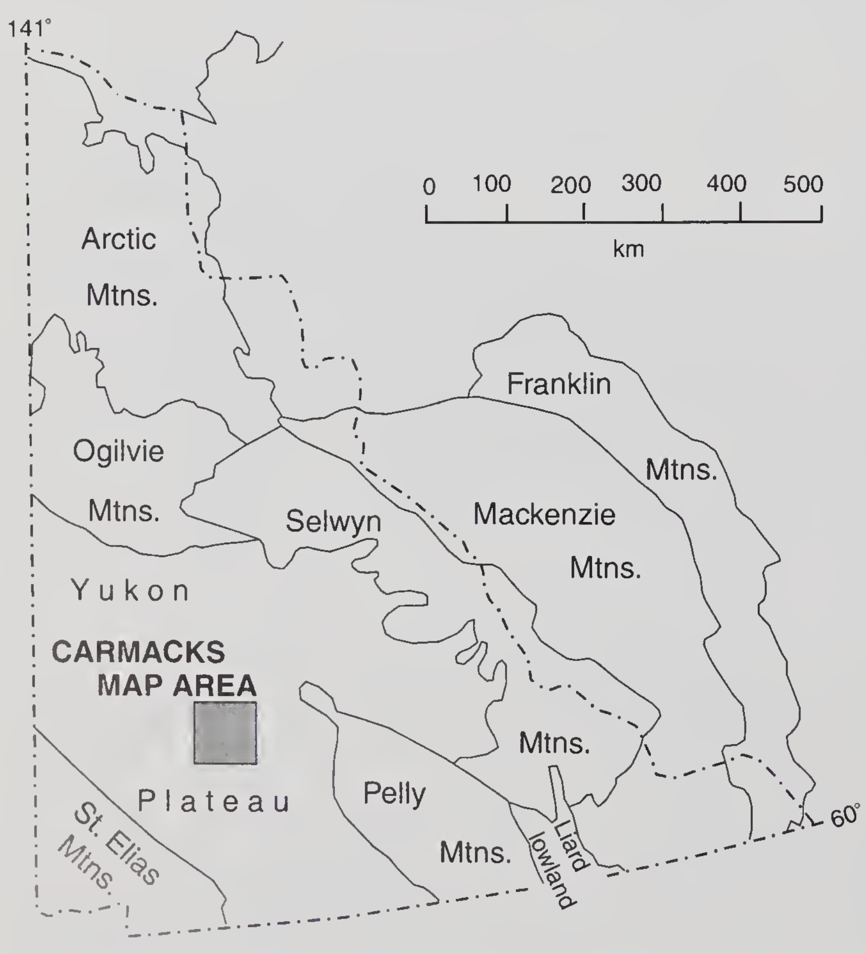


Figure 1. Generalized physiographic regions of Yukon Territory and location of Carmacks map area.

The rolling morphology of the contemporary Yukon Plateau with higher mountain groups rising above the generally accordant summits is inherited from a period when the region was eroded to a relative relief of less than about 550 m. Because no deposits from latest Cretaceous or Tertiary exist in the area, the termination of this period of erosion, uplift, and incision of the Yukon plateaus in this region is not known. Previous estimates of the age of this surface have ranged from Eocene to Miocene (Bostock, 1936; Tempelman-Kluit, 1980).

Maximum local contemporary relief is in the order of 750 to 900 m from summit to valley bottom with the lowest elevation of 415 m found on the floor of the Yukon River valley along the northwest margin of the map area. Drainage patterns are generally dendritic, trellis where major faults control stream courses, or recurved trellis where trunk streams follow the curvilinear boundaries of plutonic bodies or other nonlinear discontinuities in the bedrock. Drainage is disrupted in areas of thick bog, drift, and dune sands.

Abundant and widely spaced geomorphic evidence suggests that the contemporary northwest-flowing drainage network was preceded by another with flow largely to the south (Fig. 3, in pocket). This older network is most apparent in the configuration of the Black Creek basin where the trunk valley is up to 2 km wide and the broad valley (locally 5 km wide) presently occupied by Von Wilczek, Łütsaw, and Tthe Ndu lakes and the underfit Von Wilczek and Willow creeks. These drainage systems were once integrated into an ancestral south-flowing Yukon River system (Tempelman-Kluit, 1980). The ancestral Yukon River followed the present valley as far south as Carmacks. Beyond this, it may have followed the valleys occupied by the contemporary Nordenskiold River or Yukon River (Tempelman-Kluit, 1980) or have alternated between the two. The drainage basin of ancestral Lonely Creek, in the southwestern quarter of the map area, is tributary to what is now the headwaters of Klaza River. Glacially induced stream capture diverted much of this drainage west across the Dawson Range into Nisling River (Bostock, 1936; Hughes, 1990).

The evolution of drainage in the Carmacks map area will be further discussed in the subsequent section on glacial history.

Climate

The Carmacks map area shares the sub-Arctic continental climate of southern Yukon Territory with long, bitterly cold winters, short mild summers, low relative humidity, and low to moderate precipitation (Table 1). Intrusions of mild air from the Pacific Ocean into this region moderate the region from the Arctic climate that characterizes northern Yukon Territory (Wahl and Goos, 1987). Climate in the Carmacks map area is modified by relief. For example, temperature decreases with increasing elevation during the summer months, but during the winter, extremely cold air is frequently trapped within the Yukon River valley and other major valleys causing a temperature inversion so that air temperature often increases with elevation (Wahl et al., 1987). Although the climate is periglacial and falls within the zone of widespread permafrost (Brown, 1978), no glaciers occur within the map area due to aridity and elevations below the regional firn limit. Contemporary glaciers in the interior of Yukon Territory are restricted to montane areas in excess of 2000 m where the orographically enhanced mean annual precipitation exceeds 600 mm. Even during the last (McConnell) glaciation when the firn line fell to approximately 1500 m and the eastern one-third of the map area was occupied by the digitate margin of the Cordilleran Ice Sheet, the Dawson Range was too arid to support alpine glaciers. However, degraded cirques occur in the Dawson Range as does till entirely of Dawson Range provenance (Map 1876A). These indicate that there were one or more glaciations of Dawson Range prior to the McConnell Glaciation (LeBarge, 1995).

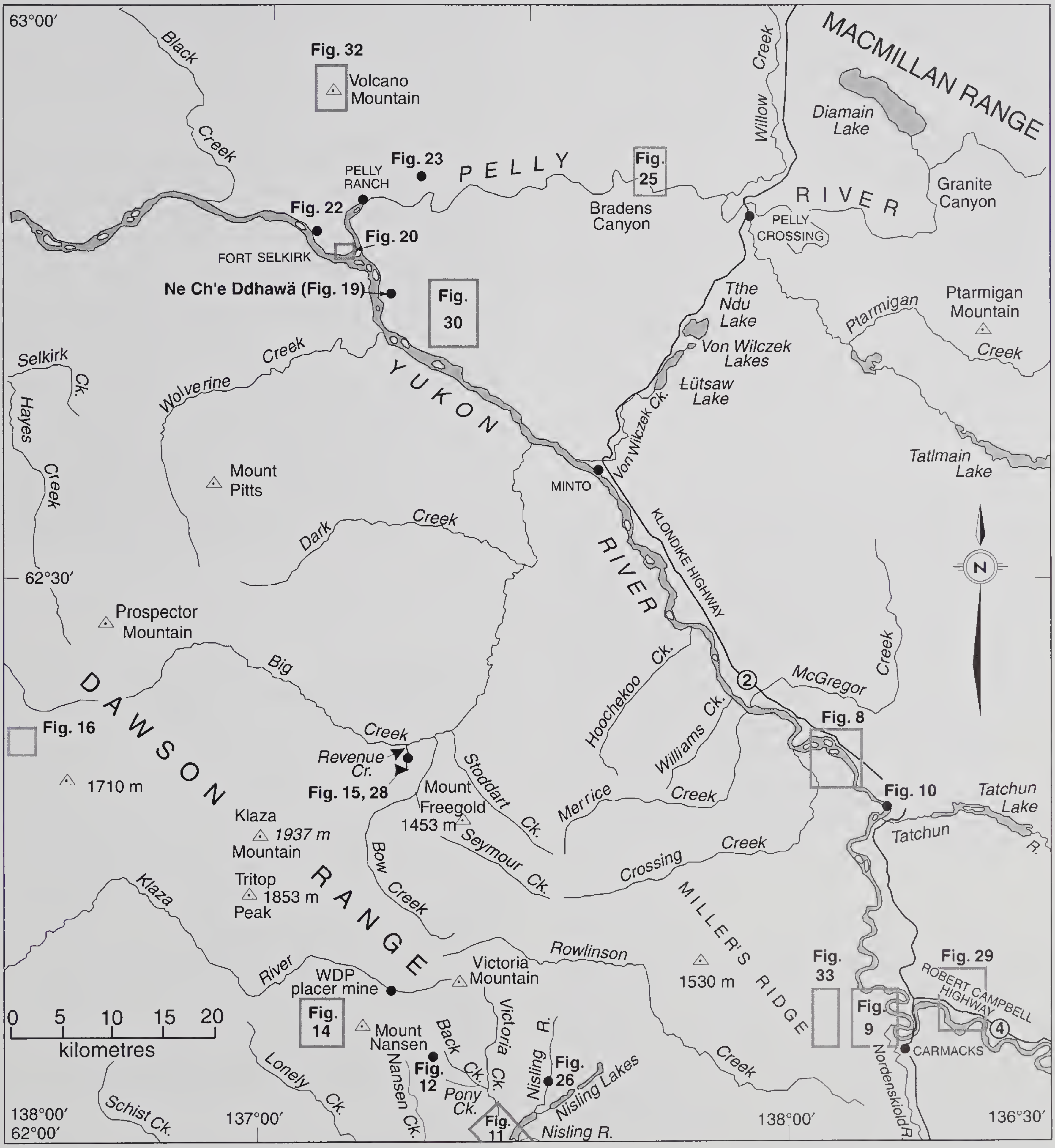


Figure 2. Major drainage features and locations of figures and sites discussed in this report. Areas covered by airphotos are denoted by rectangles; labelled dots indicate hand-held camera photographs of geological features.

Table 1. Selected climatic data for Carmacks and Fort Selkirk weather stations, Yukon Territory.

CARMACKS 62°6′N 136°18′W Elevation 523 m Period 1951–1980	January	July	Annual
Daily mean temperature (°C)	-28.2	14.5	-3.8
Extreme maximum	6.0	35.0	35.0
Extreme minimum	-57.8	-1.1	-57.8
Mean precipitation (mm)	18.4 (snow)	42.3 (rain)	254.3 (rain + snow)
FORT SELKIRK 62°49′N 137°22′W Elevation 454 m Period 1951–1980	January	July	Annual
Daily mean temperature (°C)	-30.2	14.8	-4.7
Extreme maximum	8.3	32.2	35.0
Extreme minimum	-58.9	-2.8	-60.0
Mean precipitation (mm)	20.6 (snow)	49.5 (rain)	286.4 (rain + snow)

Vegetation

Vegetation is determined by elevation, topography, and microclimate including the presence or absence of permafrost. The forest is dominated by black spruce (*Picea marianna*), white spruce (*Picea glauca*), and aspen and balsam poplars (*Populus tremuloides* and *Populus balsaminifera*, respectively). *Picea marianna* dominates under poorly drained conditions and commonly indicates the presence of underlying permafrost. Lodgepole pine (*Pinus contorta*) is scattered along Yukon River on well drained terraces and is found as high as 1200 m near the summit of Volcano Mountain. Above timberline (at about 1220 m) dwarf birch (*Betula glandulosa*) and reindeer moss (*Claddonia* spp.) dominate. Only crustose lichens and scattered herbaceous plants survive at the highest elevations or on steep, unstable or highly exposed areas. Wet areas are dominated by *Sphagnum* spp. and sedge (*Carex* spp.) bogs.

Soils

Recent soils (neosols), those that have formed during the Holocene, are widespread and fall mainly into the Regosolic Order in steep areas and above treeline and into Gleysolic and Organic orders in poorly drained locations. Cryosols are present where permafrost is within 1 m of the surface. Brunisols dominate under well drained forest conditions (Tarnocai, 1987). Recent soils developed on deposits of the last (McConnell) glaciation have been named Stewart soils. Little mineralogical alteration of the parent material from the McConnell Glaciation has been noted in these soils (Tarnocai, 1987).

Two paleosols are found in the Carmacks map area. In addition to strictly pedological differences from the (contemporary) Stewart neosols, they are frequently cut by ice-wedge pseudomorphs and sand wedges and are capped by or contain ventifacts. The Diversion Creek paleosols are believed to have developed during the last (Sangamonian) interglacial period ca. 128–115 ka BP (Smith et al., 1986; Tarnocai et al., 1985). These soils are up to two times thicker than their McConnell Glaciation equivalents, have B horizon colours the same or slightly more intense that Stewart soils, and frequently have Bt horizons with thin clay skins on ped surfaces. These soils survive at the surface on glaciofluvial terraces (Tarnocai, 1987). They are also seen in cliff bank exposures where they are buried beneath loess and alluvial fan sediments contemporaneous with McConnell glaciation events (Ward, 1993, p. 74).

The Wounded Moose paleosols developed on drift of the pre-Reid glaciations in the early Pleistocene. The paleosols have been truncated by erosion so that only part of the B horizon and the parent material are preserved. These soils are dramatically different from Stewart and Diversion Creek soils. Solum thicknesses reach 2 m. The Bt horizons (enriched in clay due to illuviation) are deeply weathered with thick clay skins present on pebbles and ped surfaces. These clay skins are the product illuviation of clay from former "A" horizons long since eroded. Munsell soil colours range from 5YR for outwash and 7YR for till parent materials to the 10YR coloration that characterizes Stewart and Diversion Creek soils (Tarnocai, 1987). Despite their coloration, sodium pyrophosphate extractable Fe and Al are too low to qualify them as podzols under the Canadian System of Soil Classification (Canadian Soil Survey Committee, 1978). They most closely resemble a Luvisol under that scheme (Smith et al., 1986). Analysis of the mineralogy of B horizon clays led Foscolos

LEGEND FOR FIGURE 4

QUATERNARY

Undivided glacial deposits, alluvium, and bog

Selkirk volcanics: basalt, basaltic hyaloclastite, and minor interstratified glacial deposits

UPPER CRETACEOUS

Carmacks Group: basalt, andesitic basalt, volcanic sandstone and conglomerate

MID-CRETACEOUS

Mount Nansen Group: andesite, dacite and rhyolite

Casino granodiorite (plutonic phase of Mount Nansen Group)

JURASSIC AND/OR CRETACEOUS

Whitehorse Trough: feldspathic sandstone, granite pebble conglomerate, andesitic basalt, and breccia

JURASSIC

Tatchun batholith: foliated biotite-hornblende granodiorite.

TRIASSIC

Minto pluton: foliated biotite-hornblende granodiorite

PALEOZOIC

Granite to granodiorite gneiss

Amphibolite, greenstone, dunite, mylonite, blastomylonite, muscovite-quartz schist and gneiss

Major fault

et al. (1977) to conclude that Wounded Moose soils developed under a climatic regime significantly warmer and with greater effective precipitation than those prevailing during the formation of the Diversion Creek and Stewart soils; mean annual temperature would have to have been at least 7°C warmer than the contemporary one with a mean annual precipitation of more than 500 mm. The length of time for soil formation would have to be comparable to the present (Holocene) interglaciation at a minimum.

BEDROCK GEOLOGY

The rocks of central Yukon Territory have been subdivided into tectonostratigraphic terranes by Tempelman-Kluit (1978). Each terrane includes rocks possessing stratigraphies and tectonic histories distinct from and unrelated to adjacent terranes. Terranes are bounded by major structural discontinuities. The Carmacks map area includes the Yukon cataclastic and the Yukon crystalline terranes and the Whitehorse Trough (Fig. 4).

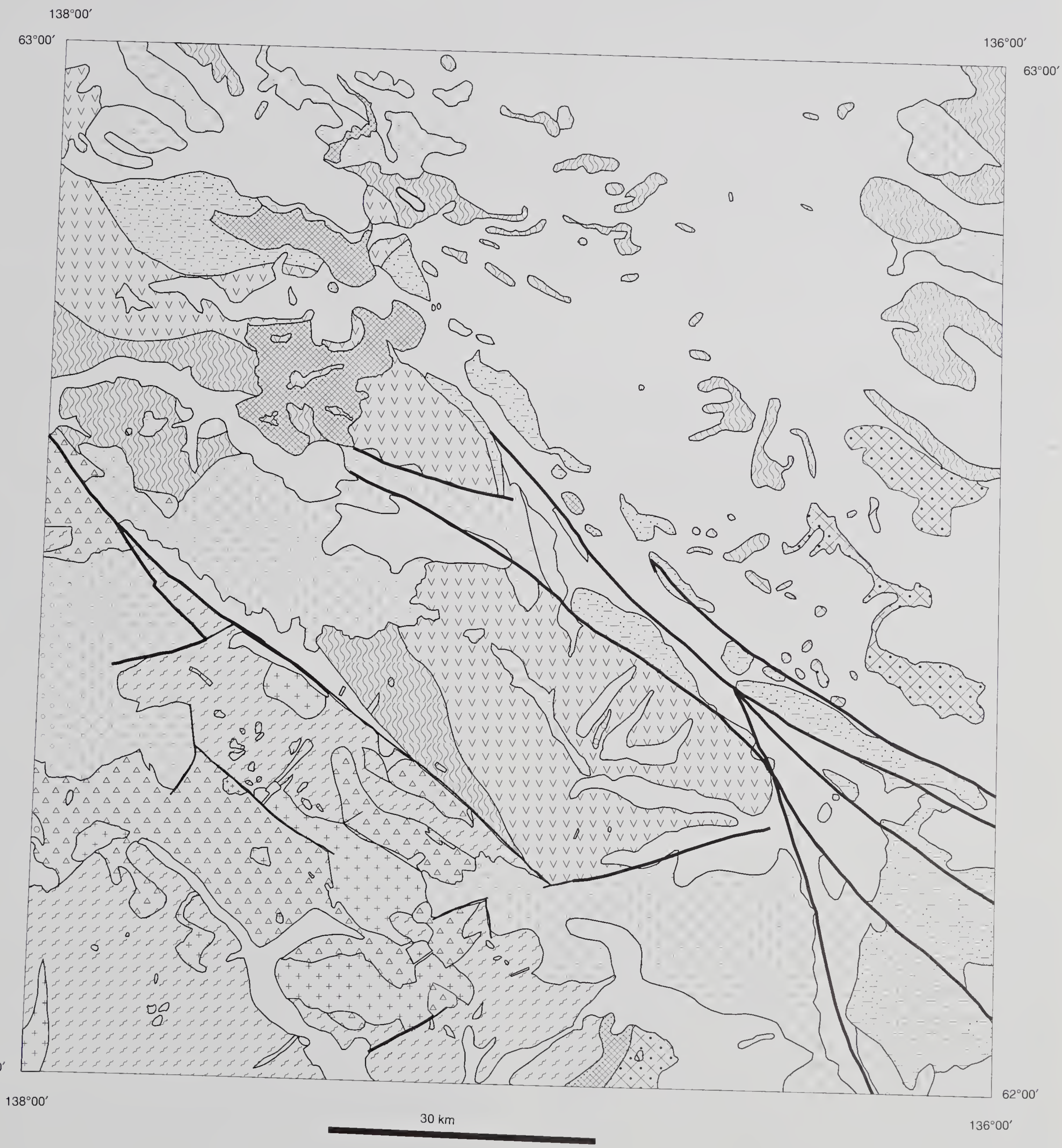


Figure 4. Generalized bedrock geology of the Carmacks map area (modified from *Tempelman-Kluit, 1984).*

These terrains are composed of Paleozoic to Jurassic sedimentary and volcanic rocks and their cataclastic equivalents. These are locally intruded by Triassic and Jurassic plutons. The Whitehorse Trough is a former fore-arc basin which received volcanolithic and arkosic clastic material from the late Triassic through Cretaceous. These terranes were sutured during episodes of continental accretion by the middle to late Cretaceous. Suturing was accompanied by the intrusion of biotite leucogranite, biotite hornblende granodiorite, and hornblende syenite plutons which extensively underlie the southwest quarter of the map area. The mid-Cretaceous andesite, dacite, and rhyolite bodies of the Mount Nansen Group were erupted in the southwestern quarter of the map area during or shortly after suturing. The extensive basalt flows and related volcanoclastic sediments of the Carmacks Group formed extensively throughout the map area during the latest Cretaceous. Renewed but very limited basaltic volcanism occurred in the Fort Selkirk area during the early Pleistocene with the eruption of the Selkirk volcanics, largely during one of the early Pleistocene glaciations of the region. Volcano Mountain, a cinder cone, erupted during the early Holocene or late Pleistocene and possibly as late as the mid-Holocene (Jackson and Stevens, 1992).

PREVIOUS WORK

Although European exploration of the Carmacks map area dates back to 1843 when Hudson's Bay Company trader and explorer Robert Campbell first visited this part of Yukon Territory (Wright, 1976), geological investigation of the Carmacks map area began with George Dawson in 1887 (Dawson, 1887). Dawson reached the area by descent of Pelly River and departed by ascending Yukon River. Among his observations were the limits of the last glaciation. Subsequent observations by geologists during the last decade of the nineteenth century and the first decade of the twentieth century were primarily concerned with bedrock and only incidental mention of Quaternary sediments was made (McConnell, 1888, 1908; Russell, 1890; Hayes, 1892; Tyrrell, 1901; Cairns, 1910, 1912). However, Hayes (1892) was the first to publish observations on the thick lava flows that form a palisade opposite the site of Fort Selkirk and the presence of the cinder cone now known as Volcano Mountain, both of which are the products of Quaternary volcanism (Jackson et al., 1990; Jackson and Stevens, 1992).

Cairns (1912) made the first geological examinations of gold placer deposits in the map area along Nansen and Victoria creeks and commented upon the upper limits of glacial deposits in the basins of these streams. No further bedrock or Quaternary geological investigations were carried out until H.S. Bostock began his regional mapping of central Yukon Territory in 1931. He produced the first comprehensive map and report of the bedrock and surficial geology of the Carmacks map area (Bostock, 1936). Bostock also recognized nonglacial gravels directly beneath and interstratified with Selkirk volcanics. Observations made in the Carmacks map area eventually became the core of a four-fold glacial-stratigraphic scheme for central Yukon Territory (Bostock, 1966). Owen (1959a, b) first noted the presence of glacial sediments beneath the volcanic rocks, thus confirming a Pleistocene age for the overlying volcanics. Dubois (1959) made the first investigation of paleomagnetism within the Selkirk volcanics and determined a reversed polarity for the samples he collected. Further limited results that corroborated Dubois' findings were reported by Naeser et al. (1982). Sinclair et al. (1978) investigated ultramafic (spinel lherzolite) xenoliths common in the basalt and volcanoclastic units of the Selkirk volcanics. Tempelman-Kluit (1984) remapped the bedrock geology of Carmacks map area. Included in his map is a relative age subdivision of the lava flows erupted from Volcano Mountain. Fuller (1986) examined late Holocene changes in the Yukon River channel and determined rates of floodplain accretion using the White River tephra as a datum. Klassen and Morison (1987) produced the first surficial geology map of the eastern half of Carmacks map area at a scale of 1:250 000. Frances and Ludden (1990) investigated the petrochemistry of the Selkirk volcanics and mapped their extent in detail. They determined their compositions to range among nephelinite, basanite, and alkaline olivine basalt. Jackson (1989) described evidence of subglacial volcanic eruptions near Fort Selkirk during the pre-Reid glaciations. Westgate (1989) reported radiometric ages determined on basalt and interstratified Fort Selkirk tephra samples. Jackson et al. (1990) made a preliminary report of an extensive investigation of the magnetostratigraphy of the Selkirk volcanics and interstratified sediments. Jackson et al. (1996a) completed this investigation. They investigated the eruptive environments, history, and geochronology of the Selkirk volcanics and the interstratified glacial sediments using paleomagnetism as the primary correlation tool. They assigned the older pre-Reid glaciation to the middle reversed interval of the Matuyama Chron (1.77–1.07 Ma) and favoured placing the younger pre-Reid glaciation within the youngest reversed interval of the Matuyama Chron (0.99–0.78). Jackson and Stevens (1992) placed middle to early Holocene age limits on the latest eruption of Volcano Mountain. They also noted a previously unmapped eroded volcanic edifice immediately west of Volcano Mountain which may have been the source of the valley-filling basalt flows along Yukon and Pelly rivers.

LeBarge (1995) investigated the sedimentology of placer gravels in the Mount Nansen area of Dawson Range. He recognized a pre-Reid till deposited by glaciers originating within Dawson Range.

QUATERNARY CONTEXT

Central and southern Yukon Territory has been glaciated at least seven times since the late Pliocene (Jackson et al., 1991; Table 2). Evidence of four glaciations of central and southern Yukon Territory was constructed by Bostock (1966) based upon morphostratigraphic, stratigraphic, and geomorphic evidence. These were named Nansen (oldest), Klaza, Reid, and McConnell (youngest). Deposits of the two oldest and most extensive glaciations have been largely removed by erosion or buried by colluvium and discrimination between them is not usually possible. Furthermore, as will be subsequently discussed, the till used to define the Nansen Glaciation appears to have been deposited during the younger Klaza

Table 2. Glacial stratigraphy of southern Yukon Territory (*modified from* Hughes et al., 1989).

Age	Yukon Plateau[1]	Snag-Klutlan area[2]	Shakwak Trench	Southern Ogilvie Mountains[3]	Liard lowland[4]
HOLOCENE	Postglacial (Stewart soil)	Neoglaciation Slims Nonglacial interval	Neoglaciation		
	------------------	13.7 ka BP ------	12.5 ka BP ------	--------------------	--------------------------------
	McConnell Glaciation	Macauley Glaciation	Kluane Glaciation	Last glaciation	Glaciation
PLEISTOCENE	Diversion Creek soil		Boutellier nonglacial		Nonglacial
	Sheep Creek Tephra (ca.190 ka)	Old Crow tephra (ca. 140 ka)	interval		
	Reid Glaciation	Mirror Creek Glaciation	Icefield Glaciation	Intermediate glaciation	Glaciation
	Wounded Moose and Pony Creek soils		Silver nonglacial interval		Nonglacial ------232 ± 21------ Glaciation ------545 ± 46------ Glaciation
	--780 ka ---------	-------------------	-------------------	-------------------	-------------------------------
	Younger pre-Reid (Klaza) glaciation		Possible age of Shakwak Glaciation		
	Nonglacial (Fort Selkirk tephra)				
	Older pre-Reid (Nansen) glaciation		Possible age of Shakwak Glaciation		

[1] Bostock (1966); Hughes et al. (1989); Jackson et al. (1990); Jackson and Harington (1991); Jackson et al. (1996a); Jackson et al. (in press)
[2] Rampton (1971)
[3] Vernon and Hughes (1966)
[4] Klassen (1987)

Glaciation (*see* 'Late Tertiary and Quaternary history'). Consequently, the terms Nansen and Klaza are abandoned in this paper in favour of the terms older and younger pre-Reid glaciations, and their distributions are combined together as pre-Reid glaciations (Table 2). The limit of glacial ice cover during the McConnell Glaciation is usually sharply defined by end moraines and ice marginal channels. The McConnell limit is better preserved than the Reid limit. Glacial landforms from McConnell Glaciation have sharper crests and greater relief and McConnell terrain is marked by many small and large lakes. This is in marked contrast to Reid Glaciation terrain where ice limits and other glacial landforms are usually poorly defined due to a long period of postdepositional erosion or burial beneath McConnell eolian sediments.

Terraces graded to the McConnell limit can be traced from the Carmacks area to Minto along Yukon River and from Granite Canyon to Bradens Canyon along Pelly River. Terraces graded to deposits of the Reid Glaciation can be traced from the McConnell limits in the Yukon and Pelly river valleys to the western margin of the map area and beyond.

The last Cordilleran ice sheet in Yukon Territory

Only the events of the last (McConnell) Glaciation are known in any detail (Jackson et al., 1991) and serve as a model for interpreting the older glaciations. Hughes et al. (1969) assigned names to semiautonomous sectors of the McConnell Glaciation Cordilleran Ice Sheet in southern Yukon Territory. These sectors (Selwyn, Cassiar, and Liard lobes) are defined in Figure 5. The Selwyn Lobe flowed west from Selwyn Mountains and shared a common ice divide with the Liard Lobe in the area of Finlayson Lake on the Continental Divide. The Cassiar Lobe flowed west and northwest from the Cassiar Mountains. It was separated from the Selwyn Lobe by Pelly Mountains. The Liard Lobe flowed south from Selwyn Mountains and southeast and east, respectively, from Pelly and Cassiar mountains. Pelly Mountains supported complexes of ice caps which shed ice to the Cassiar and Selwyn lobes as well. The Eastern Coast Mountain Lobe, which flowed northeastward from the summits of the eastern Coast Mountains in northwestern British Columbia, was intermediate between the piedmont lobe complex originating

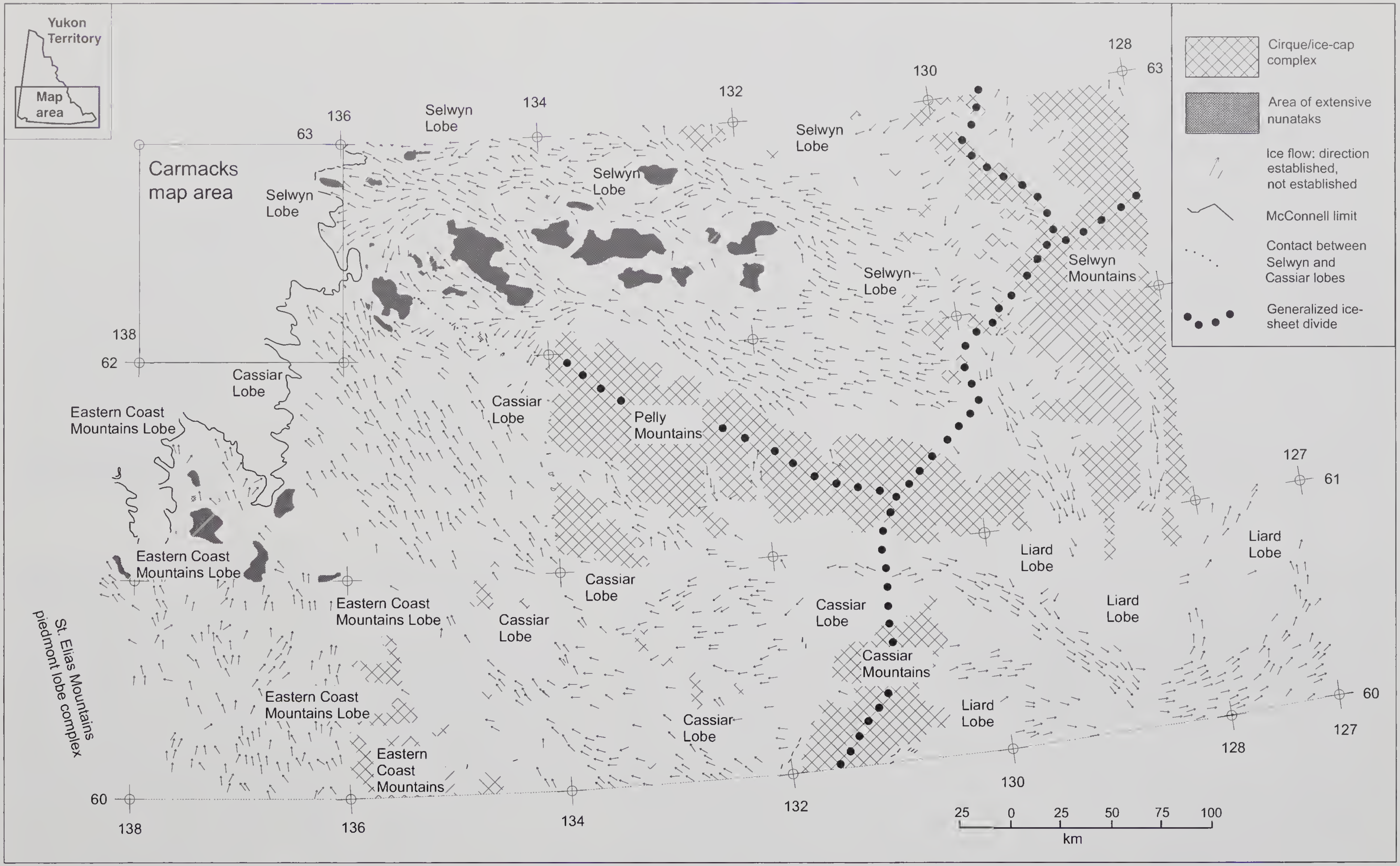


*__Figure 5.__ A reconstruction of the last Cordilleran Ice Sheet in southern Yukon Territory showing ice-flow patterns, ice divides, cirque and ice-cap complexes, and nunataks (*after *Jackson and MacKay, 1990). It is divisible into Selwyn Lobe, which flowed west from Selwyn Mountains; Cassiar Lobe, which flowed northwest from Cassiar Mountains; eastern Coast Mountains Lobe, which was shed by the eastern Coast Mountains; a piedmont lobe complex from St. Elias Mountains, and Liard Lobe, which flowed eastward toward Mackenzie River valley. The Pelly Mountains shed ice to the Selwyn, Cassiar, and Liard lobes. The southwestern corner of Carmacks map area received ice from the Cassiar Lobe, whereas the northeast corner received ice from the Selwyn Lobe.*

in St. Elias Mountains and the Cassiar Lobe. Parts of two of these sectors (Selwyn and Cassiar) are included within the study area.

THIS STUDY

The majority of field operations in the Carmacks map area were carried out during the summers of 1988 and 1989 with short periods of follow-up work in 1990, 1992, and 1993. The surficial geology of the area was first mapped on airphotos then the airphoto interpretation was checked on the ground. The reconnaissance mapping of Klassen and Morison (1987) over the eastern half of the map area was checked, detailed, and corrected where it was found to be inaccurate. Traverses were carried out by helicopter, truck, foot, and boat. In total 269 stations were described in the field. These descriptions ranged from airborne observations to detailed descriptions of cliff bank exposures.

QUATERNARY DEPOSITS

Quaternary deposits exposed at the surface in the report area formed almost entirely during the McConnell and Reid glaciations, the intervening interglacial, and the Holocene. Older Quaternary deposits are usually buried by colluvium or wind-blown deposits, or lie beneath basalt of the late Pliocene–early Pleistocene phase of the Selkirk volcanics. Some units such as till dating from the pre-Reid glaciations are exposed only in scattered exposures along river valleys or in artificial exposures and are represented in stratigraphic sections presented on accompanying 1:100 000 scale surficial geology maps 1876A (Victoria Creek; NTS 115-I, southwest portion), 1877A (Victoria Rock; NTS 115-I, northwest portion), 1878A (Granite Canyon; NTS 115-I, northeast portion), and 1879A (Tantalus Butte; NTS 115-I, southeast portion). These deposits and the Selkirk volcanics are described in detail in the 'Quaternary deposits' and 'Map units and stratigraphy' sections later in this report.

Classification of landforms and surficial materials

The earth materials portrayed in maps 1876A, 1877A, 1878A, and 1879A are broadly divided into the following three supergroups: 1) bedrock comprising pre-Quaternary consolidated materials, 2) early Quaternary volcanic rocks, and 3) middle and late Quaternary unconsolidated or poorly consolidated sediments. These have been in turn subdivided using a simplified version of the British Columbia Terrain Classification System (Howes and Kenk, 1988). In this system, surficial materials are initially subdivided according to genesis and then further subdivided on the basis of morphology and modifying surficial processes, although the latter are usually indicated with a symbol. Other properties such as texture and stratification are implicit within these subdivisions. It has also proven to be easier and useful to represent landslides, rock glaciers, and thin eolian and organic coverings as symbols rather than letter designators.

Genesis

Bedrock (R)

Bedrock includes rock older than late Tertiary which is completely exposed or has a thin, patchy covering of colluvium or till. In alpine areas, the rock surface may be fractured and cryoturbated into blockfields, sorted stone polygons, and solifluction lobes.

Late Pliocene and Pleistocene volcanic rocks and interstratified sediments (V)

See 'Sediments and volcanic rocks of the pre-Reid glaciations and interglacials'.

Morainal deposits (M)

Till is a diamicton i.e. an unsorted, matrix-supported, massively bedded to poorly stratified sediment ranging from clay to boulders in texture (Fig. 6). Till has been the most widely used term in North America for morainal deposits.

Figure 6.

Till deposited during the McConnell Glaciation, Crossing Creek about 30 m east of the McConnell glacial limit. Photograph by L.E. Jackson, Jr. GSC 1999-012A

The recent great advances in the understanding of ancient glacial sedimentary environments through the investigations of contemporary glacial and nearby glacially influenced environments e.g. Bolton (1970), Shaw (1979, 1985), Lawson (1981, 1988), and Eyles et al. (1983) have led some sedimentologists to advocate use of the term "till" be restricted only to a sediment which can be demonstrated to have been deposited beneath flowing ice by lodging (Lundqvist, 1980). Classification schemes have been devised for glaciogenic deposits based upon precise knowledge of their origin (*see* Dreimanis (1988) for a history of classification schemes). However, in practice, these have very limited value in Quaternary mapping and stratigraphy over broad areas (Lundqvist, 1980). They are of limited use because in reality, tills from different sedimentary environments have many overlapping properties that commonly make them indistinguishable in the field (Driemanis, 1988, Appendix D; Levson and Rutter, 1988). It follows that minor, debatable differences can cause major differences in interpretation. Furthermore classification schemes are in a state of flux, placing terminology for glaciogenic sediments in peril of being superceded in a few years (Levson and Rutter, 1988). In this report, the term till is used *sensu lato* after Dreimanis (1982): "Till is a sediment that has been transported and is subsequently deposited by or from glacier ice with little or no sorting by water." He included within this definition diamicton redeposited by gravitational processes contemporaneously with deposition from ice i.e. while ice still underlies or is in the vicinity of the sediment. The mappability of diamicton units of glacial origin i.e. their continuous or nearly continuous distribution over areas of many square kilometres, is regarded as one of the hallmark properties in calling them till.

Till ranges in thickness from thin and discontinuous veneers less than 1 m thick to 5 m or more. It is also a component of hummocky ice-stagnation topography and of lateral and end moraines near present-day glaciers. Ice stagnation topography is characterized by closely spaced small hillocks and ridges several metres to 10 m in height. These were likely formed as till melted out from the ice or slid into depressions between blocks of stagnant ice (Boulton and Eyles, 1979).

Figure 7 plots the less than 2 mm textures of unweathered McConnell, Reid, and pre-Reid tills from the Carmacks map area along with 18 samples of till from the Glenlyon map area (NTS 105 L) immediately to the east (Ward, 1993). The predominantly sandy textures of till in the Carmacks map area are artifacts of the glacial erosion of the largely granitic and schistose bedrock traversed by the Cordilleran Ice Sheet in this area. This contrasts with the more argillaceous terrain in the areas immediately to the east in Glenlyon map area (up ice-flow in the former Selwyn and Cassiar lobes of the Cordilleran Ice Sheet). The samples of pre-Reid till analyzed for texture were taken from buried till units exposed along the Yukon River in the Fort Selkirk area. Where pre-Reid till is encountered near the surface, it is largely weathered to clay. This clay-rich weathered till is economically important in placer districts because its cohesiveness makes it sufficiently resistant to erosion to form a false bedrock upon which paystreaks have locally accumulated. It may also be a gold-producing unit where pre-existing placer gravel was incorporated into till (LeBarge, 1995).

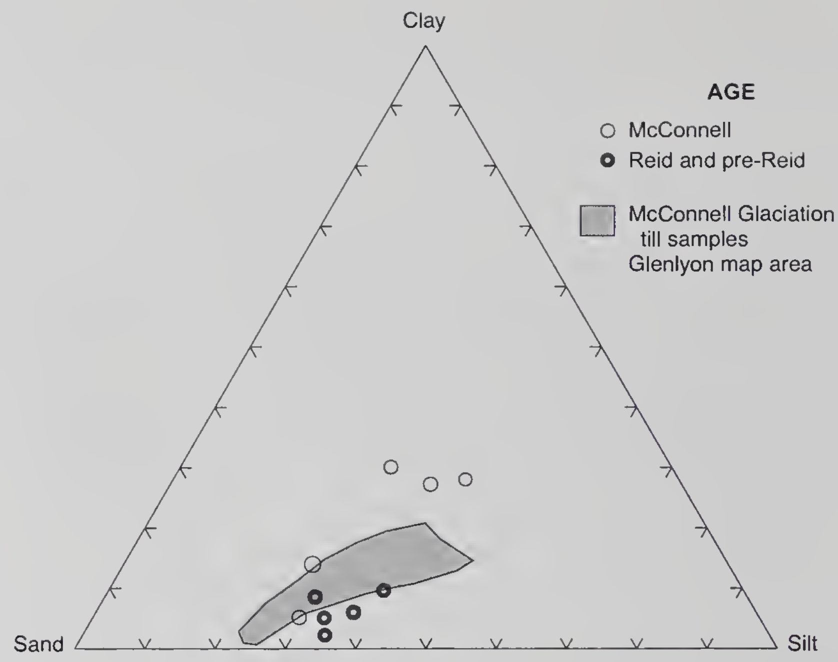


Figure 7. *Sand, silt, and clay textures for tills of three ages in Carmacks map area (NTS 115-I). The shaded area shows the range of textures for 18 till samples from the McConnell Glaciation in Glenlyon map area (NTS 105 L) immediately east. The greater range of textures in the Carmacks area reflects the greater heterogeneity of its bedrock geology.*

Unweathered tills in the map area are low in carbonate content. Eight samples had between 1.5% and 9% total carbonate with a mean value of 5.1%.

Glaciofluvial deposits (G)

Glaciofluvial deposits are deposits of sand and gravel and varying components of diamicton, sand, and silt laid down by running water on top of, against, and flowing away from glacial ice. Sorting ranges from good to poor, and stratification from thin bedded to massive. Beds are frequently lensoidal and textures and sedimentary structures may change dramatically both laterally and vertically over a few metres. Sediments commonly display evidence of syndepositional collapse due to meltout of buried or supporting ice.

Distal glaciofluvial sediments include outwash plain (valley train) deposits ('T' on Fig. 8). Proximal sediments include ice-walled channels, kames, deltas, eskers, and crevasse fillings (Fig. 9).

Glaciolacustrine deposits (L)

Glaciolacustrine sediments are predominantly silt, clay, and fine sand deposited in lakes dammed in valleys by the Cordilleran Ice Sheet during its maximum extent (e.g. deposits in Rowlinson Creek valley) or during its wasting stages (e.g. sediments in the area of the confluence of Yukon River and Tatchun River).

Thicknesses range from 1 m to more than 30 m in thick valley fill along Yukon River in the Tatchun River confluence area (Fig. 10). Topography on these sediments is typically rolling to planar where distal sedimentation prevailed, and hummocky or ridged in proximal areas where sedimentation

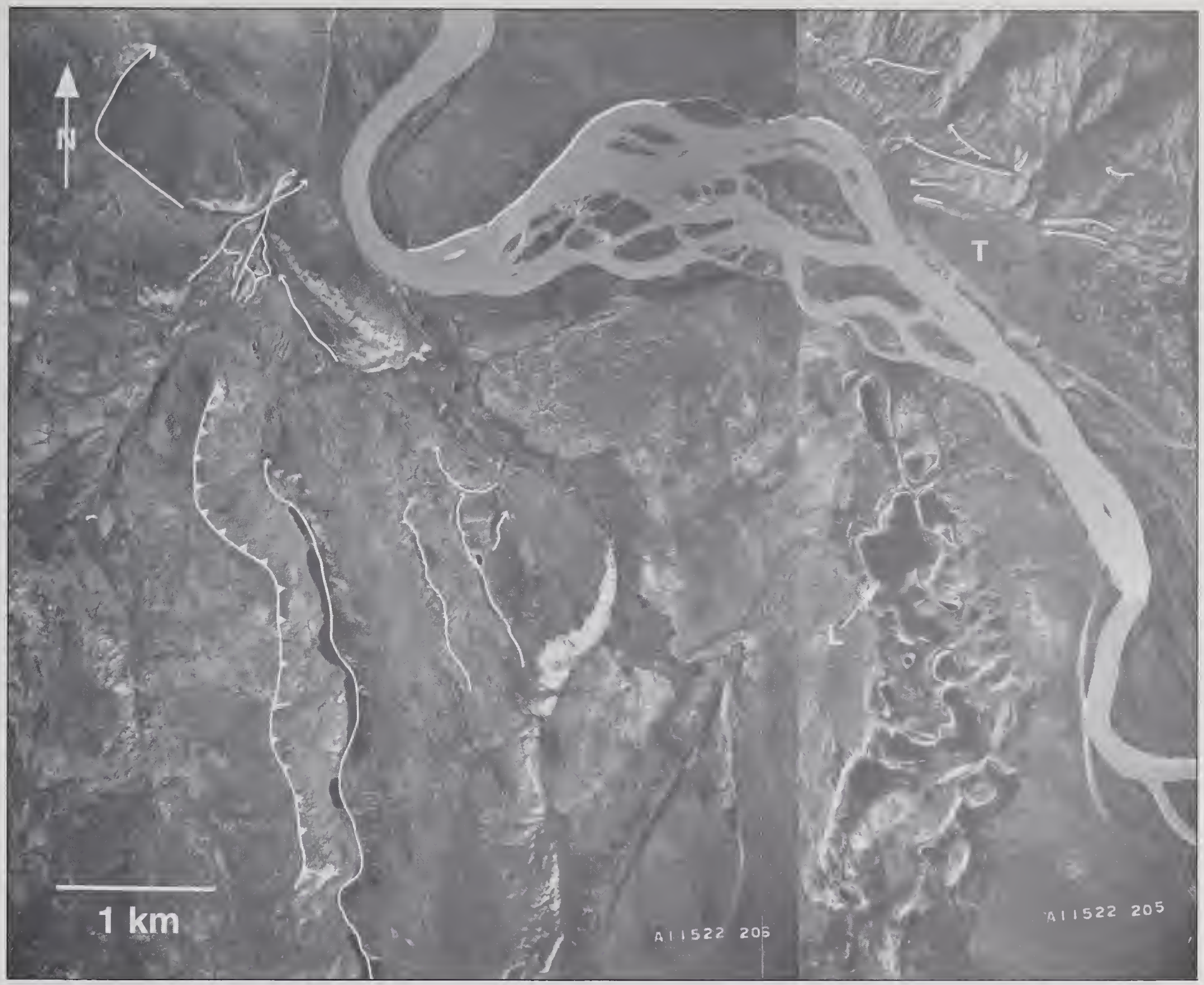


Figure 8. *Airphoto mosaic of the area of the McConnell Glaciation terminus of the Yukon River valley glacier. The former glacier terminus is marked by toothed line (teeth on former ice side) which follows the upper limit of till, trim features, and lateral moraines. The uppermost ice-marginal meltwater channels (arrows) also indicate the upper limits of the McConnell glacier. The flights of ice-marginal meltwater channels descend toward the centre of the valley and mark the progressive thinning and retreat of the glacier after reaching its maximum position (just beyond the northern limit of the field of view). The prominent lakes in the centre of the valley (L) mark an area where stagnant ice was buried by outwash gravel. The highest McConnell terrace level begins at T. NAPL A11522-205, -206*

occurred on or around stagnant ice. Where sedimentation was removed (distal) from ice margins, sediments are rhythmically bedded, sand-silt or silt-clay, normally graded couplets complicated locally by slumping or diapiric deformation reflecting the rapid deposition from suspension or turbidites of these low-permeability sediments (Eyles et al., 1983; Smith and Ashley, 1985). Individual or clusters of dropstones released from icebergs are also common in distal sediments.

Sediments deposited near ice margins (proximal) range from silt to coarse gravel and diamicton. They reflect deposition through processes as diverse as meltout from floating and grounded icebergs, debris flow from ice margins, fluvial deposition by supraglacial and subglacial streams, and settling of fines from suspension and subsequent deformation triggered by ice meltout and slumping (Eyles et al., 1983).

Alluvial deposits (A)

Alluvial deposits are gravel and sand which were deposited by streams not fed by glacial meltwaters. Within larger valleys they are commonly overlain by or grade laterally into lacustrine or organic sediments in poorly drained areas of floodplains. In practice, mapping on the basis of this definition encounters some difficulties in areas glaciated during the Reid and McConnell glaciations. Modern floodplain and alluvial

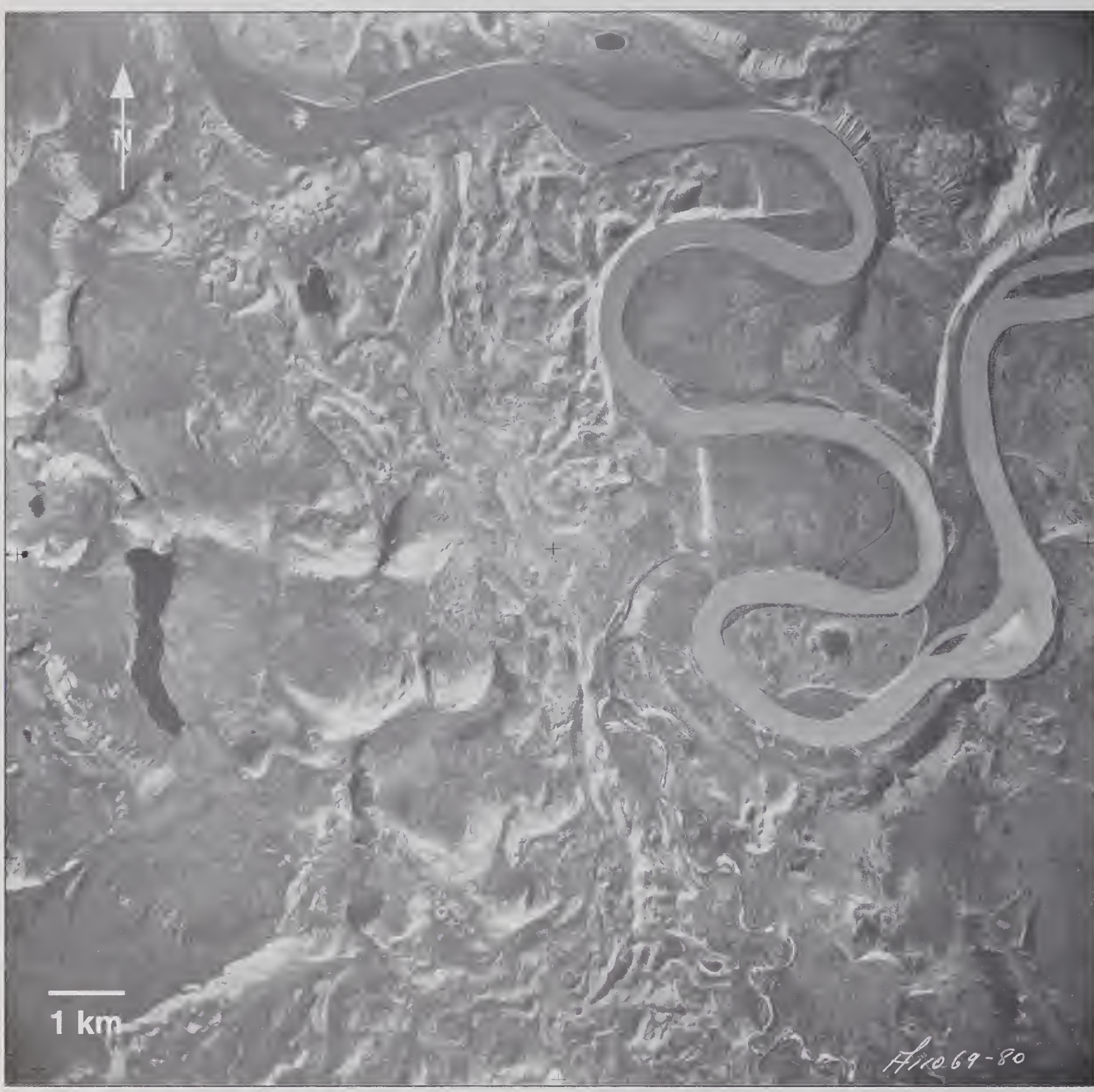


Figure 9. Extensive ice stagnation topography immediately south of Carmacks along Yukon River. NAPL A11069-80

fan deposits are readily identified whereas older terraced deposits cannot be as easily distinguished as being of fluvial or glaciofluvial origin.

A further complication is the fact that many of the terraced fluvial deposits may be of paraglacial origin (Ryder, 1971a, b; Church and Ryder, 1972; Jackson et al., 1982). Paraglacial sediments are laid down during the final stages and following deglaciation. Glaciation leaves significant quantities of unconsolidated and unstable glacial deposits within mountainous areas. These deposits are available for mobilization by mass wasting and fluvial erosion. This rapid delivery of sediment into the fluvial system without a commensurate increase in overall fluvial discharge leads to fan building and trunk-stream aggradation followed by terrace cutting as the sediment supply wanes. This decrease in sediment supply occurs as available glacial sediment within mountain watersheds dwindles and nonglacial rates of erosion are approached. For the purposes of this report, paraglacial sediments are included under the fluvial heading rather than glaciofluvial.

Figure 10. *Thick glaciolacustrine fine sand and silt (L) overlying the terminus of a till (T) deposited during a readvance of the retreat phase of McConnell Glaciation. Gravel (G) was deposited as outwash graded to the ice terminus. Yukon River is in the foreground. Photograph by L.E. Jackson, Jr. GSC 1999-012B*

In Dawson Range, thick angular gravels and sands formed under periglacial conditions during the Reid Glaciation (*see* 'Reid glaciation'). These units (Fig. 11; section 2, Map 1876A; section 6, Map 1879A) locally overlie auriferous placer gravels which were deposited during a period of stream degradation between the pre-Reid and Reid glaciations (Jackson, 1993; LeBarge, 1995). In mountainous reaches of first- and second-order streams in areas beyond the limit of the Reid Glaciation, angular gulch gravels grade laterally with colluvial mantles and are interstratified with amalgams of organic and eolian sediments with minor alluvial sediments known as muck since the Klondike gold rush. The gulch gravels are noteworthy because they locally contain economic deposits of placer gold in Dawson Range.

Colluvial deposits (C)

Colluvium includes the most diverse group of deposits, usually sandy diamicton, and landforms to be lumped together under a single heading. The term is applied to deposits originating by the in situ breakdown of bedrock and unconsolidated sediments followed by gravitational transportation and resedimentation. Along broad summits in the Dawson Range which have never been glaciated, mineral exploration trenches such as those viewed between Back and Pony creeks reveal that coarse angular colluvium extends more than 3 m below the surface (Fig. 12). Most colluvial deposits and their landforms are end or intermediate members in continuous spectra as depicted in a classification scheme for colluvial landforms of the study area. Figure 13 depicts plots of the texture of the colluvial sediments comprising landforms versus events which build or shape these landforms. Clast support increases with increasing boulder content in colluvial sediments until, in talus aprons and cones, significant void space occurs between clasts. Conversely, increasing sand, silt, and clay content (<2 mm size fraction) results in matrix-supported sediments although a significant boulder content remains, i.e. solifluction deposits. The rates of formational events indicated in Figure 13 are based upon rates measured for similar deposits elsewhere. On the extreme upper left of the diagram are talus aprons and cones. These are built by small rockfalls from adjacent bedrock cliffs. The entire rockfall event beginning with the failure of rock on the cliff face and ending with the cessation of movement of the last rock particle on the talus apron is very short – tens of seconds. Hundreds of these short duration events may occur in a single year (Gardner, 1979, 1980, 1983). Where bedrock slopes are less precipitous, snow avalanching, slush flows, and debris flows build colluvial fans. Fluvial processes play a secondary role in winnowing and redeposition on colluvial fans although nonfluvial gravitational processes and their deposits dominate. There is a continuum of landforms between cones that are predominately built by colluvial processes to those that are fluvially dominated.

Colluvial deposits formed by cyclical freeze-thaw activity are placed on the right side of Figure 13. Cycles may range from diurnal to seasonal. Sediment texture varies with bedrock lithology, jointing patterns, and slope angle. Also, colluvial deposits may be interstratified with silt or fine sand or have a significant silt or fine sand component to their matrix due to incorporation or burial of eolian deposits.

Felsenmeer or blockfields and sorted stone polygons occur above the treeline on blocky jointed resistant bedrock units such as granitic rocks and hornfels and contain little fine sediments. However, less resistant units such as shale break down to form sediments with relatively high contents of fine particles and low permeability. Saturation of the upper metre of this material during seasonal thaw reduces material strength to the point where slow flow or creep occurs. This has resulted in the formation of a colluvial blanket formed of solifluction lobe complexes on slopes above timberline. In the Dawson Range, a colluvial blanket has descended from

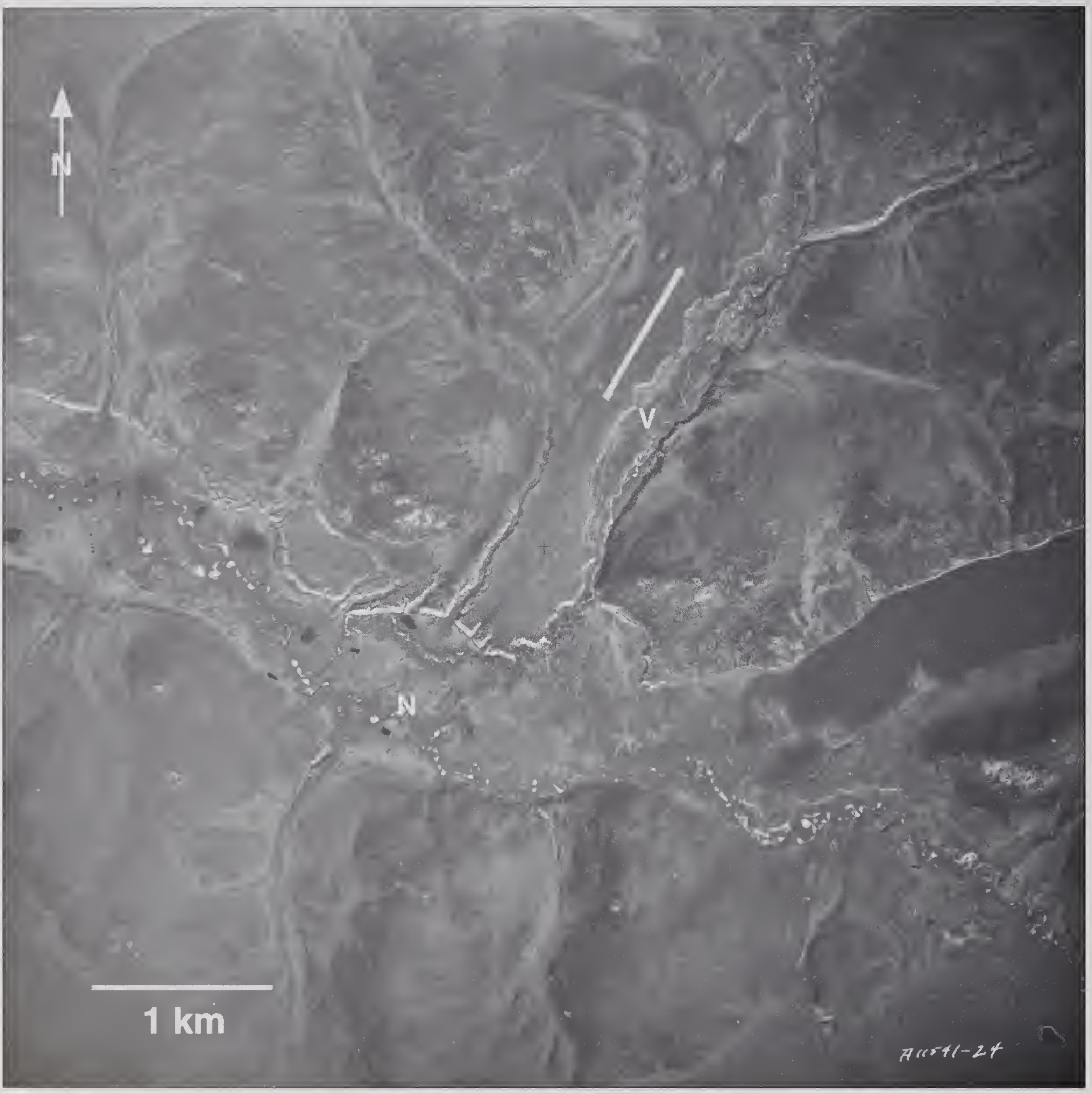


Figure 11. Airphoto of a terrace in the valley of Victoria Creek (V) near the confluence with the west-flowing Nisling River (N). The terrace is underlain by at least 15 m of gravel (see *section 2, Map 1876A). Approximately the upper 10 m of the gravel fill was deposited during the Reid Glaciation by Victoria Creek. The Victoria Creek basin was beyond the limit of glacier ice at that time. The gravel fill was graded to the Cordilleran Ice Sheet or a lake dammed by it at the climax of Reid Glaciation. NAPL A11541-24*

Figure 12.

Colluvial cover, Dawson Range. Tape measure is 50 cm long. Colluvium formed by the in situ physical disintegration of rock locally exceeds 3 m on level sites in this area. Photograph by L.E. Jackson, Jr. GSC 1999-012C

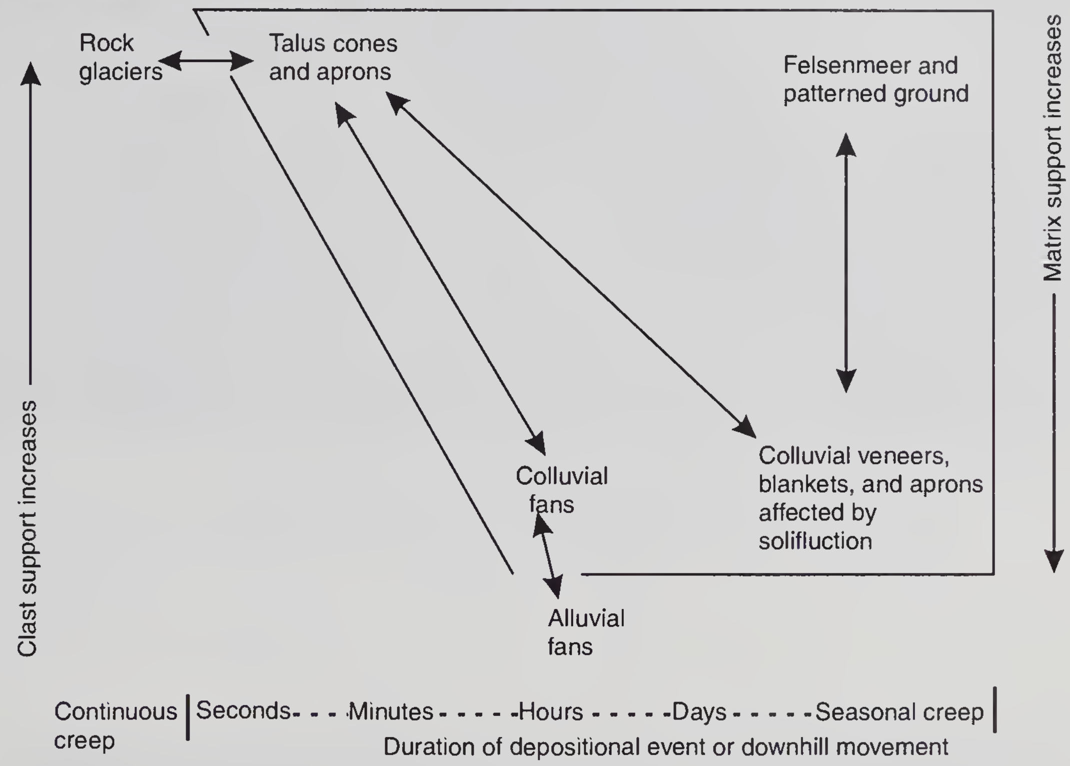


Figure 13.

Plot of rate of formation and texture of colluvial sediments.

the ridges and summits burying the early Pleistocene landscape including deposits of the pre-Reid glaciations. Denudation is locally markedly uneven. Competent bedrock has locally resisted physical weathering and outcrops out of the colluvial covering as tors (Fig. 14; denoted by a symbol in maps 1876A to 1879A). Dawson Range has many spectacular examples of these castellate features. They locally rise 10 m or more above surrounding ridge surface.

Eolian deposits (E)

Eolian deposits include wind-deposited silt, sand, and tephra which form dunes, blankets, and thin and discontinuous cappings upon surficial deposits and bedrock.

Organic deposits (O)

Organic deposits are accumulations of vegetal materials, chiefly peat, with varying amounts of fine windblown and colluviated mineral sediments and interstratified alluvial sands and gravels (Fig. 15). These deposits are found in high water-table areas such as floodplains, shallow paludifying lakes, and low areas close to or below the water table in hummocky moraine. Beyond the limits of glacial ice cover during the McConnell Glaciation and particularly beyond the Reid limits, they also cover slopes as blanket bog where the underlying permafrost forms an impervious substrate to snow melt and rain waters during the summer months. In these areas thick deposits grading from reworked organic-rich loess to silty peat (muck) fill upland valleys and cap underlying coarse gulch gravels. Organic deposits host permafrost and contain lenses of clear ice. Palsas or palsen, peaty mounds and plateaus raised above the surrounding surface by the growth of underlying clear ice lenses, are common in organic deposits within marshes and floodplains throughout the area. Open system pingoes (Fig. 16; denoted by a symbol on maps 1876A to 1879A) are small hillocks created by the growth of a large ice body within or beneath organic deposits along the base of a slope (Hughes, 1969). The ice body is fed by water flowing under hydrostatic pressure. These typically collapse when the elevation of the pingo causes xeric conditions at the

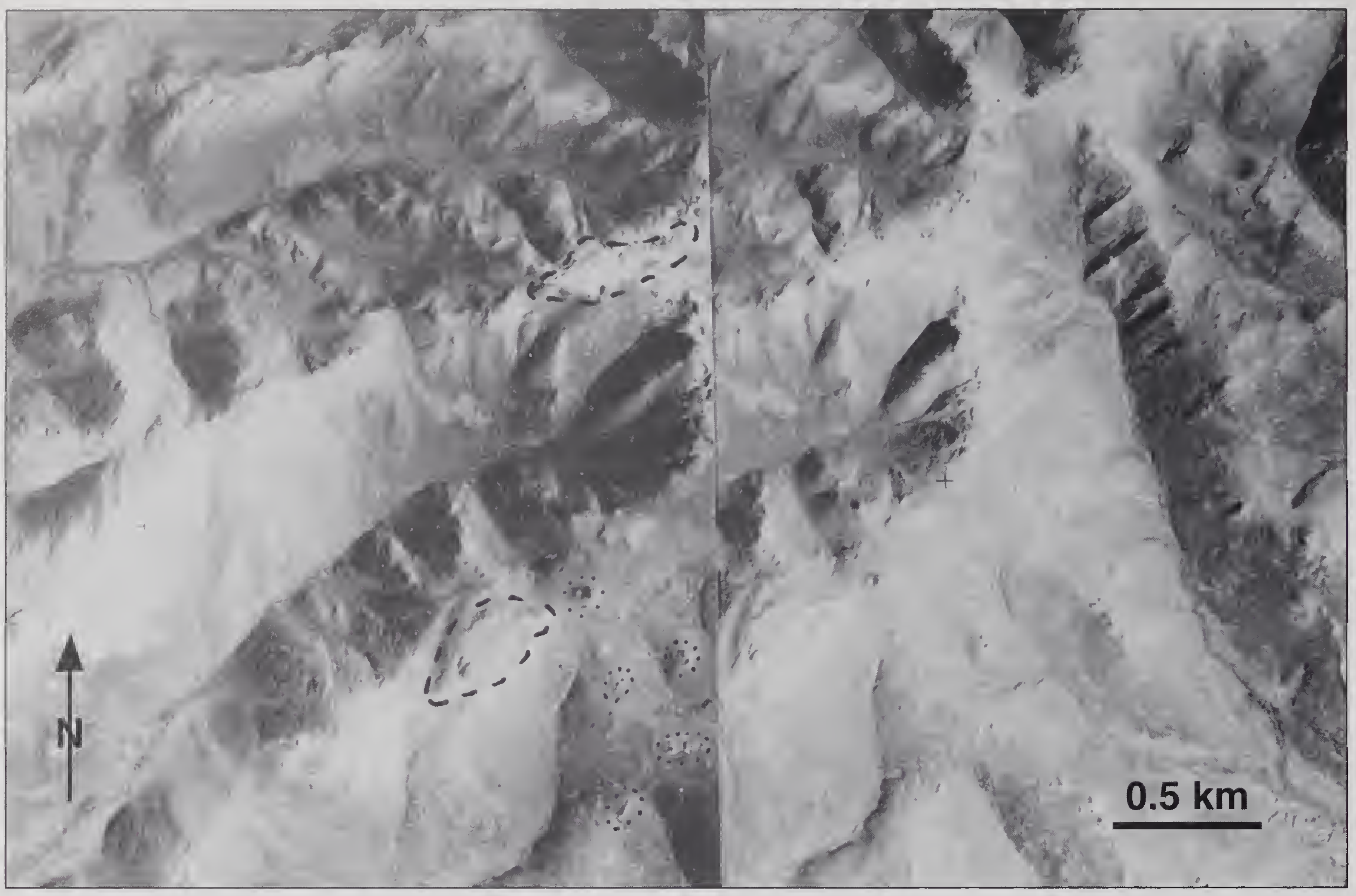


Figure 14. Airphotos (stereo pair) of tors (outlined by dots) and altiplanation terraces (surrounded by dashes), Mount Nansen, Dawson Range. NAPL 11472-432, -433

Figure 15.

Organic sediments, Revenue Creek. Succession is formed by beds of peat, logs, organic silt interstratified with pebbly, organic-rich fluvial sand and fine gravel. Photograph by L.E. Jackson, Jr. GSC 1999-012D

Figure 16. *Arrow indicates an open system pingo in a typical setting in the nearly continuous permafrost terrain of Dawson Range. The pingo is situated along the toe of a slope composed of blanket bog, alluvial fans, and colluvial blankets. A cross-section of the deposits comprising the pingo would be similar to that shown in Figure 15. NAPL A11539-360*

pingo summit and the insulating organic cover begins to degrade causing melting. These are most commonly found beyond the limits of ice during the Reid Glaciation.

Landforms

Landforms are defined on the basis of slope, shape, spatial distribution, and relationship to surrounding geomorphic features. The landforms used to subdivide Quaternary deposits are listed below (modified from Clague, 1982).

Apron (a)

Aprons are planar to semiplanar sloping surfaces along slope toes marking areas of accumulation of sediments derived from the adjacent slope through fluvial and colluvial deposits. They typically form through the coalescence of individual fans and cones. Apron slopes can range from less than 10° to more than 35°.

Blanket (b)

Blanket is a continuous or nearly continuous mantle of sediment more than 1 m thick but thin enough to generally conform to underlying topography.

Delta (d)

A delta is a deltaform planar surface truncated at its broad margin by an abrupt scarp. It marks the site of sediment deposition at the former confluence of a stream with a standing body of water.

Fan (f)

A 'fan' can be defined as a fan-shaped landform that is a conic sector which descends from its apex to its semicircular margin. Fans are constructional landforms built at the mouth of a tributary valley or a ravine or gulley. Steep fans with slopes in excess of 15° are referred to as cones.

Plain (p)

'Plain' can be defined as a flat or very gently sloping (0–3°) surface with local relief generally less that 1 m marking the surface of an accumulation of sediment.

Terrace (t)

Stepped or benched topography consisting of one of more well defined scarps separating horizontal or gently inclined (0–3°) surfaces (treads) is referred to as 'terrace'.

Undivided (u)

For the purposes of this study 'undivided' is defined as two or more landform types of the same genesis that cannot be subdivided at the scale of mapping.

Veneer (v)

Veneer is a thin (<1 m) and usually discontinuous mantle of sediment that conforms to the underlying deposits or bedrock.

Complex (x)

Complex is topography consisting of ridges, pits, terraces, and channels with reliefs of 2 m to tens of metres distributed over horizontal distances of tens of metres. This complex of landforms were formed by sediment deposition in and around stagnant glacial ice.

MAP UNITS AND STRATIGRAPHY

The map units defined on the basis of the genetic and morphological criteria described in the preceding sections are described below in order of decreasing age along with units that occur in the subsurface and have been described where they are revealed along near-vertical natural exposures. These are represented as strip logs on maps 1876A to 1879A. These section are placed in time context in Figure 17 which summarizes the Quaternary stratigraphy of the map area.

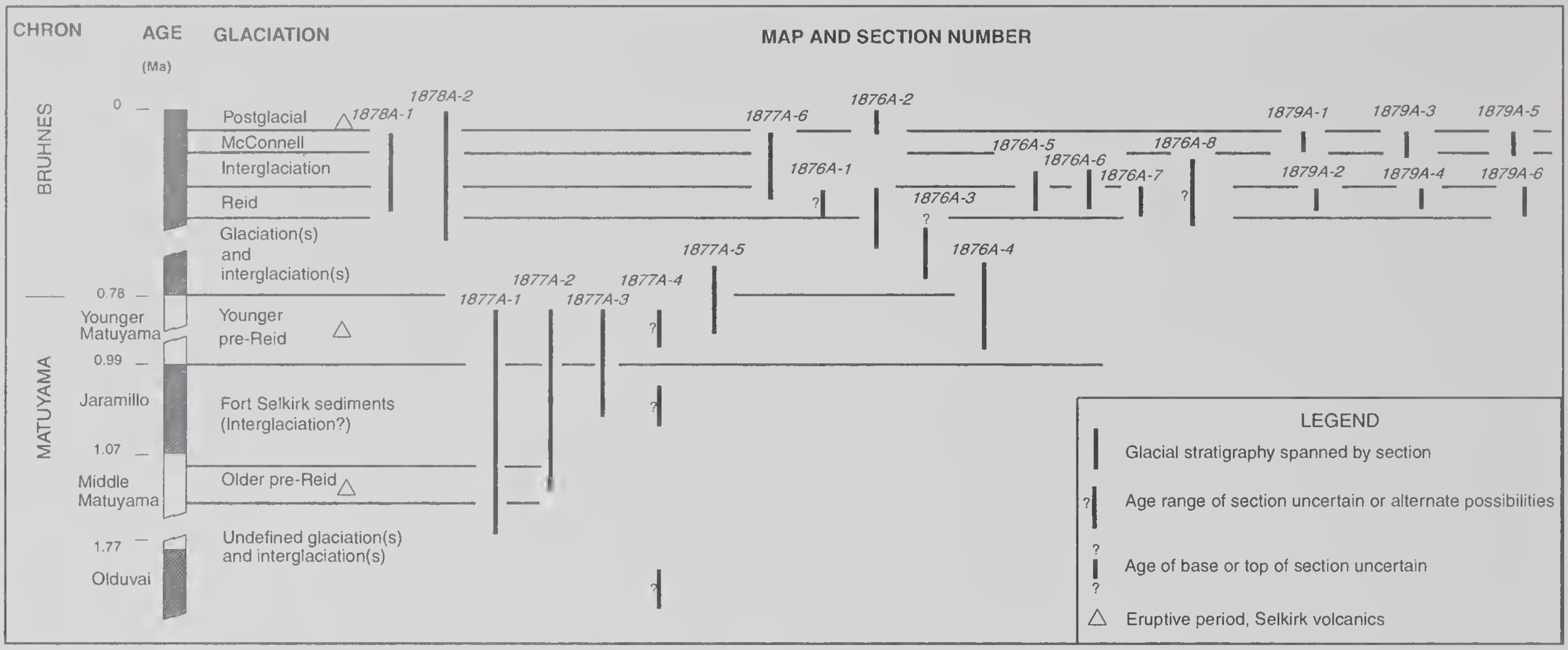


Figure 17. Summary diagram showing the glacial stratigraphic context of the Quaternary stratigraphic sediments studied in Carmacks map area. Section numbers correspond to sections depicted in detail on maps 1876A, 1877A, 1878A, and 1879A. The bases for assigning sections to glacial-stratigraphic units and the geopolarity time scale are described in the text and Jackson et al. (1996).

Pre-Tertiary (rock)

Undivided bedrock (units R, R-A)

Ridge summits and slopes not subject to snow and rock avalanche activity and ice-streamlined bedrock exposures in valley and plateau settings are mapped as 'R'. Steep escarpments and ridges including cirques and arêtes and bedrock exposures along gorges subject to snow and rock avalanching are mapped 'R-A'. Both designations may include areas covered by thin and patchy coverings of colluvium and glacial sediments.

Late Tertiary preglacial or interglacial sediments

Preglacial or interglacial gravels (subsurface)

Possibly the oldest unconsolidated deposit in the map area is a poorly exposed cobble gravel which underlies basalt flows of the Selkirk volcanics directly across the Yukon River from the ghost town of Fort Selkirk (basal gravel in section 1, Map 1877A). Although only a few 1.5 m exposures of this gravel exist immediately below the contact with the overlying basalt, float and test pits suggest that the gravel may be up to 20 m thick. The exposed portion of the gravel is massive to trough crossbedded. Clasts are predominantly resistant local lithologies; they are subrounded to rounded and markedly imbricated. Out of 45 imbrication orientations measured, all but six indicated flow from the northeast or southeast quadrants. If this is representative of the gravel body, it would indicate that the modern flow direction of the Yukon River (westernly in this area) had been established and ancestral southerly flow (Tempelman-Kluit, 1980) abandoned by the time this unit was deposited.

Age and origin

This gravel could be as old as late Pliocene if it is indeed preglacial as was first suggested by Bostock (1936). The overlying basalt has been dated at approximately 1.6 Ma (Table 3, 1877A-1; Westgate, 1989). This should be regarded as a maximum age for the basalt because the basalt units of the Selkirk volcanics tend to yield erroneously old ages (Table 3, 1877A-2 and 1877A-4). The true age of the basalt could be several hundreds of thousands of years younger (Jackson et al., 1996a). The gravel differs somewhat in maturity and composition with typical outwash gravels of the Reid and pre-Reid glaciations. Clasts are more rounded in this gravel and are predominantly resistant local lithologies such as quartz, quartzite, basalt, and granitic rocks whereas easily comminuted lithologies such as slate, schist, and cataclastic rocks, which are common in pre-Reid outwash and till, have been eliminated (compare Fig. 18A, B with Fig. 18C–G). However, this basal gravel is compositionally different than the purportedly preglacial White Channel Gravel in the Dawson area (McConnell, 1908) which is almost entirely quartzose in composition and is the product of weathering in a dramatically different late Tertiary climatic regime (Boyle, 1979). The flow reversal of the reach of the Yukon River immediately west of Fort Selkirk (Fig. 3) clearly predates the deposition of this gravel. Glacial diversion is an obvious possible mechanism for this reversal. Consequently, the possibility that this gravel postdates a glaciation that preceded the two pre-Reid glaciations represented by deposits in the Fort Selkirk area is consistent with an emerging picture of late Tertiary glaciations. Regional glaciation in central North America has been documented at more than 2.01 Ma (Hallberg, 1986) and montane glaciation in nearby Alaska extends back to the Miocene (Péwé, 1975, p. 113). More recent work has documented late Tertiary regional glaciation

Table 3. Summary of radiometric ages on basalt and tephra from Selkirk volcanics. K-Ar age determination[1] this study.

Paleomagnetism sample site	Field number	Age (Ma BP)	Wt % K^2	Radiogenic[3] Ar	% Atmospheric Ar
1877A-2	010789R1	1.276 ± 0.34	1.03 ± 0.831	0.5106×10^{-7}	74
1877A-4	290689R2	2.362 ± 0.86	1.15 ± 0.557	1.057×10^{-7}	89
1877A-4	300689R2	3.921 ± 0.11	1.22 ± 0.936	1.857×10^{-7}	79
1877A-4	260689R5	2.078 ± 0.055	1.44 ± 0.651	1.166×10^{-7}	83
Previously published K-Ar ages on basalt					
Paleomagnetism sample site		**Age (Ma)**		**Source**	
1877A-1		1.60 ± 0.08		Westgate, 1989	
1877A-2		1.35 ± 0.08, 1.35 ± 0.11, 1.47 ± 0.11		Westgate, 1989	
1877A-2		1.08 ± 0.05		Naeser et al., 1982	
Previously published fission-track ages on Fort Selkirk tephra					
(glass shards) 24 tephra		Isothermal plateau method			
		1.19 ± 0.11, 1.01 ± 0.11, 1.43 ± 0.26, 1.54 ± 0.27		Westgate, 1989	
		Standard method			
24 tephra		0.84 ± 0.13, 0.86 ± 0.18		Naeser et al., 1982	
		Standard fission track method			
(zircon) 24 tephra		0.94 ± 0.40		Naeser et al., 1982	

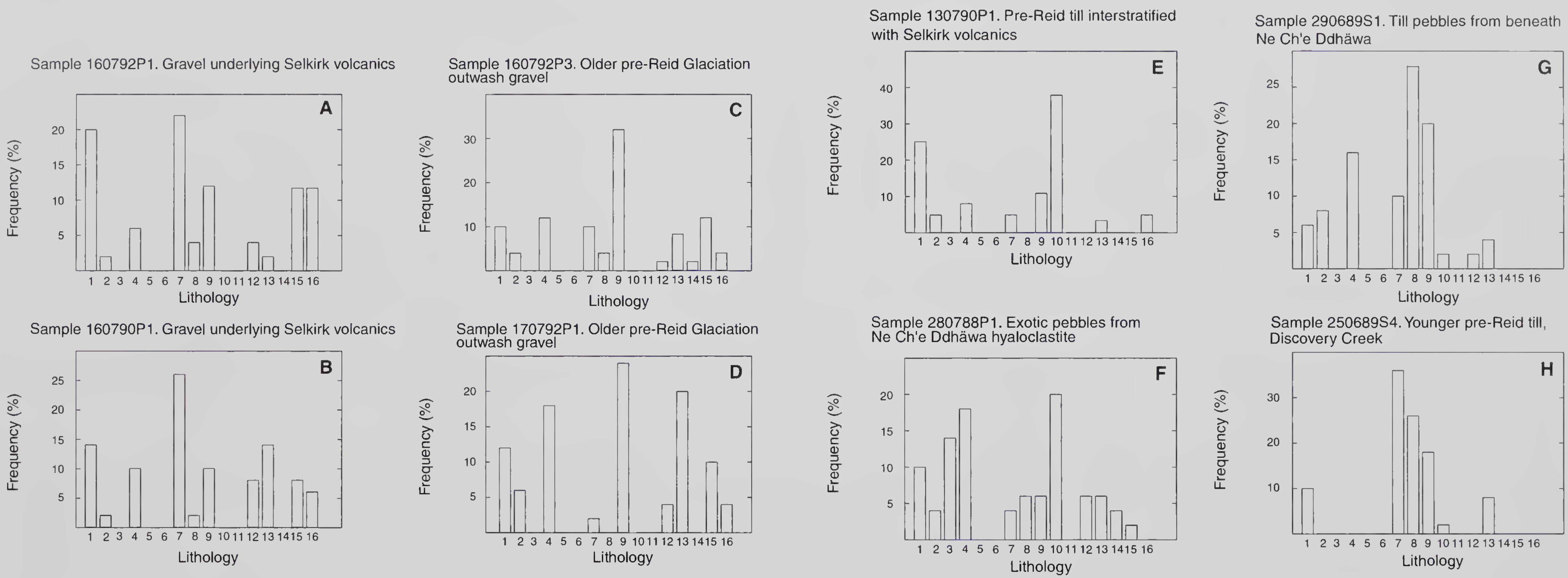
[1] Determined by the Geological Survey of Canada.
[2] Error values are 1σ.
[3] Values in cm^3/g and error value is 1σ.

in west-central Yukon Territory (Duk-Rodkin and Barendregt, 1997; Froese et al., 1997), elsewhere in the Canadian Cordillera (Duk-Rodkin et al., 1996), and in the nearby Canadian Arctic (Barendregt et al., 1998).

Sediments and volcanic rocks of the pre-Reid glaciations and interglacials

Selkirk volcanics (unit V)

The name "Selkirk volcanics" was given by Bostock (1936) to a complex of basaltic lava flows, pillow basalt, pillow breccia, and altered tuff units in the area of Fort Selkirk. This assemblage locally contains exotic pebbles (Fig. 19; Map 1877A). They principally occur in the areas of the confluence of the Yukon and Pelly rivers, in the area of Volcano Mountain, and the Wolverine Creek basin (Frances and Ludden, 1990). These basaltic volcanic rocks are locally interstratified with glacial and nonglacial sediments (Owen, 1959a, b; Jackson et al., 1990; Jackson et al., 1996a). Basalt flows form impressive palisades along the Yukon River from Pelly ranch to approximately 12 km downstream of Fort Selkirk (Fig. 20). The surface of the basalt fill gradually descends from approximately 150 m above river level near Pelly ranch to approximately 100 m near Fort Selkirk to half that amount at their downstream limit. Their descent in elevation from north to south and north to west indicates a source north of Pelly ranch. Jackson and Stevens (1992) reported an eroded volcanic edifice immediately west of Volcano Mountain which may represent the source of these flows. The cumulative thickness of basalt flows exposed along the gorge of Wolverine Creek exceeds 100 m. The basalt flows infill much of the preglacial Yukon River valley and the preglacial landscape of Wolverine Creek basin. They consist of multiple flow units of massive to columnar basalt separated by flow breccias and complexes of foreset-bedded pillows. The pillows represent delta-like deposits created as lava flows entered deep-standing water (Jackson et al., 1996a). The Ne Ch'e Ddhäwa volcanic edifice (Ne Ch'e Ddhäwa is the aboriginal name for this officially unnamed mountain; Fig. 1), composed of altered tuff, pillow tuff breccia, and pillow basalt units, rises almost 300 m above Yukon River (*see* cover photograph). It rests upon semiconsolidated, early Quaternary sediments. Only the basal metre of the 300 m succession of hyaloclastites forming this mountain is depicted in section 4, Map 1877. Jackson (1989) demonstrated that Ne Ch'e Ddhäwa erupted beneath at least 300 m of glacial ice. The hyaloclastite units of Ne Ch'e Ddhäwa are magnetically reversed and paleomagnetically



1. Sandstone and quartzite
2. Siltstone and shale
3. Feldspathic and lithic sandstone
4. Selwyn basin chert, cherty and silicified cherty sandstone and siltstone, and chert pebble conglomerate
5. Limestone
6. Dolostone
7. Felsic and intermediate intrusive rocks
8. Felsic and intermediate volcanic and subvolcanic rocks
9. Basalt and basaltic subvolcanic rocks
10. Greenstone
11. Ultramafic rocks
12. Gneiss
13. Slate, schist, dark metasiltstone, mylonite, and phyllite
14. Other metamorphic rocks (hornfels, amphibolite)
15. Quartz and quartz fieldspar veins
16. Unidentifiable, other.

Figure 18. *Lithologies of:* ***A****) and* ***B****) gravel underlying the Selkirk volcanics;* ***C****) and* ***D****) pre-Reid outwash interstratified with Selkirk volcanics;* ***E****) pre-Reid till overlying outwash and interstratified with Selkirk volcanics;* ***F****) exotic pebbles incorporated in the hyaloclastite units of Ne Ch'e Ddhäwa;* ***G****) pebbles from a till underlying Ne Ch'e Ddhäwa volcanic edifice;* ***H****) younger pre-Reid till at Discovery Creek.*

identical to the basalt flows filling Yukon and Wolverine river valleys. Consequently, all were erupted during the younger pre-Reid glaciation (Jackson et al., 1996a).

Age

Three periods of eruption (Fig. 17) have been documented by Jackson and Stevens (1992) and Jackson et al. (1996a) for the Selkirk volcanics. Eruption of the oldest basalt flows and hyaloclastite units (columnar and pillow basalt unit, section 1, Map 1877A), predated or was concurrent with the older pre-Reid glaciation which occurred during the middle reversed interval of the Matuyama Chron (1.07 Ma and 1.77 Ma). The second eruptive period, during which most of the extensive valley-filling basalt and Ne Ch'e Ddhäwa was erupted (Map 1877A), was coincident with the younger pre-Reid glaciation and occurred during the youngest reversed interval of the Matuyama Chron (0.78 Ma and 0.99 Ma) or immediately prior to the brief Cobb Mountain normal polarity event variously determined to range from 1.19 Ma (Shackleton et al., 1990) to between 1.201 Ma and 1.211 Ma (Cande and Kent, 1995). The third and most recent eruptive period was centred at Volcano Mountain. Basaltic tephra and flows were erupted at approximately the Pleistocene–Holocene boundary and possibly as recently as the mid-Holocene. Further discussion of volcanism is presented in the 'Late Tertiary and Quaternary history' section and in 'Natural hazards' discussion of the 'Applications' section.

Sediments interstratified with the Selkirk volcanics (subsurface)

Ne Ch'e Ddhäwa volcanic edifice

Ne Ch'e Ddhäwa is underlain by an unknown thickness of semi-consolidated sediments. The upper several metres of these sediments (section 4, Map 1877A) have been exposed by hand trenching and include alternating beds of stony sand and fine silty sand with intraclasts and grey clay. These beds are capped by 0.5 m of stony, clay-rich diamicton containing striated basalt clasts. This diamicton is unconformably overlain by altered hyaloclastite tuff at the base of the Ne Ch'e Ddhäwa eruptive sequence. The sand and clay sediments are folded and deformed into diapiric structures at the contact with the diamicton and are partly incorporated into it. The most likely explanation of this deformation, assuming the diamicton is of glacial origin, is by glacial overriding. However, rapid loading during the eruption of the overlying volcanic edifice or deformation during the movement of a fault a

Figure 19.

Till lens in hyaloclastite tuff breccia, Ne Ch'e Ddhäwa volcanic edifice. Photograph by B.C. Ward. GSC 1999-012E

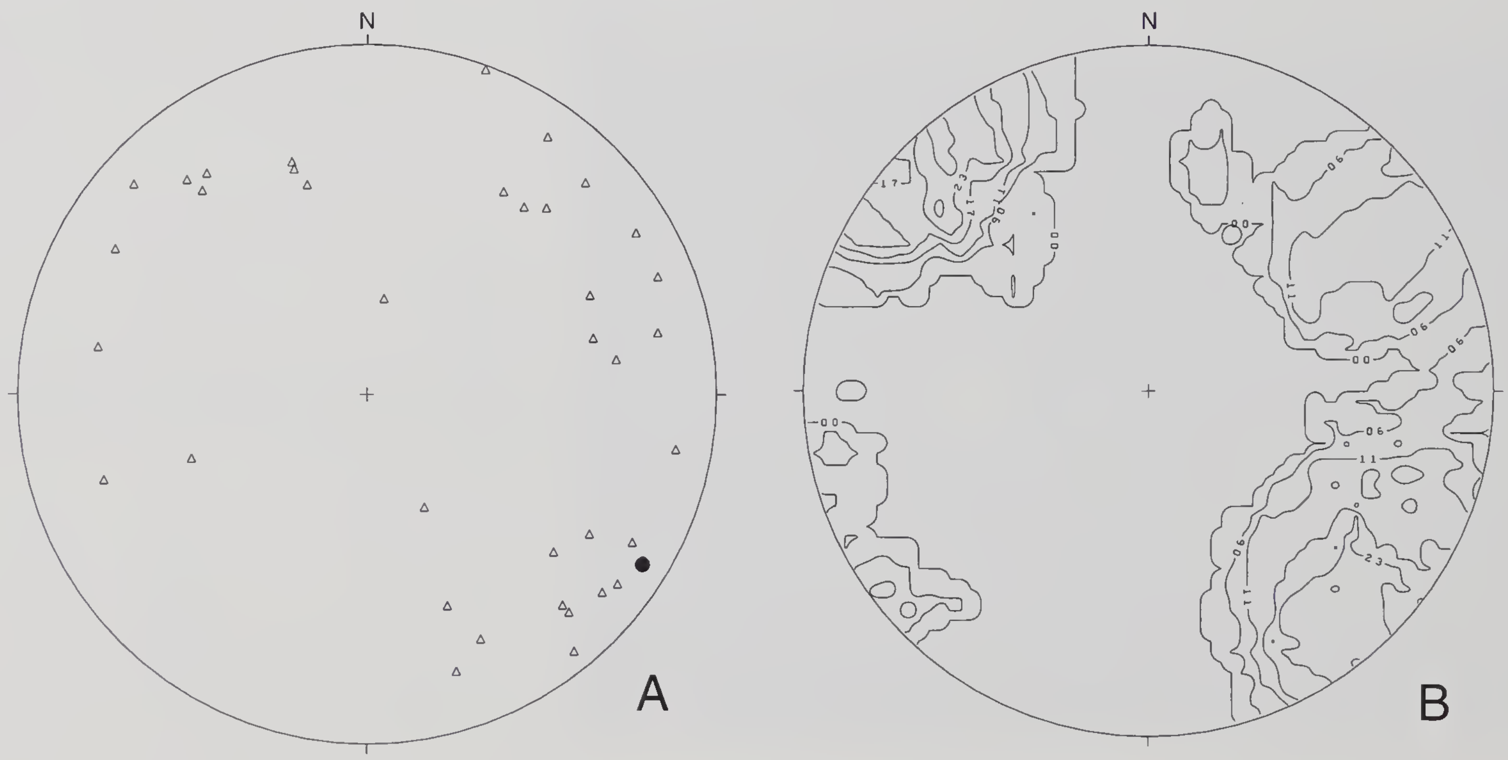
Figure 20.

Basalt flows filling the preglacial Yukon River valley at the confluence of Yukon and Pelly rivers. The palisades formed by the basalt flows are approximately 100 m high. Photograph by L.E. Jackson, Jr. GSC 1999-012F few tens of metres to the north could have caused this deformation (*see* the discussion in the 'Natural hazards' section of 'Applications').

The paleomagnetic sampling and analysis of fine silty sand within these sediments indicates them to be magnetically normal although the directions of magnetization are erratic likely due to the postdepositional deformation that affected them (Jackson et al., 1996a). The overlying Ne Ch'e Ddhäwa volcanic edifice is magnetically reversed and dates from the latest or middle reversed intervals of the Matuyama Chron (Jackson et al., 1996a). Therefore, the sediments in section 4 (Map 1877A; 1877-4 *in* Fig. 17) could date from the Jaramillo Subchron (1.07–0.99 Ma) or from an older normal magnetic period. This uncertainty is illustrated in Figure 17 by placing these sediments in several time contexts with respect to the geopolarity time scale. Some poorly preserved pollen was recovered from one of three samples of these sediments (the others were barren). Dominant trees *Picea* (spruce), *Pinus* (pine), *Betula* (birch), and *Alnus* (alder) are identical to the present forest of the area (R.J. Mott, pers. comm., 1989). Consequently, the sediments were deposited during the Quaternary rather than during the more temperate Tertiary.

Older pre-Reid glaciation till and outwash (subsurface)

Glacial deposits from the older pre-Reid Glaciation are exposed between the upper and lower basalt units along with interglacial or interstadial sediments at two sites along the Yukon River in the area of Fort Selkirk (Fig. 17, section 1877A-1, 1877A-2; sections 1 and 2, Map 1877A). At section 1, diamicton and gravel, interpreted as till and outwash, are present whereas, at section 2, only outwash is present. The diamicton is 1.5 m in thickness and light grey, stony, and extremely indurated. Its matrix is sandy. Pebble lithologies are dominated by locally occurring basalt, greenstone, schist, and cataclastic rocks. However, erratic lithologies such as chert-pebble conglomerate from the Devonian–Mississippian Earn Group are also present. These clasts have travelled at least 125 km from the nearest outcrop to the east. The diamicton is identified as till on the basis of its fabric (Fig. 21) which shows a predominance of elongate pebble plunge toward the southeast and east (the general direction from which glacial ice would enter the area) and content of streamlined and striated clasts. The overlying outwash gravel contains a similar content of lithologies as the underlying till. It fines upward from gravel to interstratified sand and gravel. At section 2



PRE-REID TILL

Projection..........................Schmidt
Number of points.........................37
Mean lineation azimuth..........121.4
Mean lineation plunge................7.0
1st Eigenvalue........................0.503
2nd Eigenvalue.......................0.351
3rd Eigenvalue........................0.146

E1/E3....................................0.359
E2/E3....................................0.880
[E1/E3]/[E2/E3].....................0.408
Spherical variance..............0.5233
Rbar...................................0.4767

△ Till pebble azimuth and plunge
● Mean lineation and plunge

Figure 21. Fabric of pre-Reid till. ***A****) Intersections of pebble axes on lower hemisphere of a Schmidt stereonet and associated statistics.* ***B****) Density contours drawn on azimuths and plunges shown in A.*

(Map 1877A), gravel is 16 m thick and overlies basalt at its base. It has a similar range of clast lithologies to those at section 1 but it is abruptly overlain by sand rather than grading upward into sand.

Age

The age of the older pre-Reid till and outwash is constrained by ca. 1.6 Ma K-Ar age for underlying lower basalt flows and the fission track and K-Ar ages for the overlying Fort Selkirk tephra (*see* below).

Fort Selkirk interglacial sediments (subsurface)

Older pre-Reid Glaciation outwash is succeeded by 3–4 m of fine sand and silt in sections 1–3 (Map 1877A; Fig. 22). These sediments were deposited during a period of ice-free conditions in the Fort Selkirk area between the older and younger pre-Reid glaciations. The informal term Fort Selkirk interglacial sediments is applied to this succession. The fine sand and silt composing these sediments were deposited in low-energy fluvial or lacustrine and eolian environments. They are in turn capped by basaltic tephra and basalt flows. Collectively, these sediments have yielded teeth from a primitive vole *Lasiopodomys* sp., fragments of limb bones from *Rangifer* (caribou), a lagomorph (rabbit or hare) about the size of the presently living *Lepus arcticus* (R. Harington, pers. comm., 1989), and degraded moss fragments. The sediments in section 1 (Map 1877A) are capped by what was believed to be lapilli which contains carbonized wood fragments.

Age

The Fort Selkirk interglacial sediments are reversely magnetized over the lower part and normally magnetized over the upper part (Fig. 17). Jackson et al. (1996a) concluded that the normally magnetized sediments were deposited either during the Jaramillo Subchron or the Cobb Mountain Subchron. The Fort Selkirk tephra (Fig. 22; Naeser et al., 1982), a fine silicic tephra ranging from 0 to 20 cm in thickness in the area, occurs within the reversely magnetized interval (Fig. 17, sections 1877A-1 and 1877A-2). Fission track ages on the Fort Selkirk tephra range from ca. 1.54–0.86 Ma; however, Jackson et al. (1996a) concluded that ages younger than 1.07 Ma on the Fort Selkirk tephra must be erroneous because it is reversely magnetized and overlain by the succession of normally magnetized sediments and reversely magnetized basalt flows. This succession of polarities would be incompatible with any deposit postdating the Jaramillo (normal) Subchron. The latest and presumably the most reliable set of fission track ages determined on it are 1.01 ±0.17 Ma, 1.19 ±0.11 Ma, 1.43 ± 0.26 Ma, and 1.54 ±0.27 Ma (Westgate, 1989). The youngest of these is clearly incompatible with the reversed polarity of this unit because almost all of the error values fall within the magnetically normal Jaramillo Subchron and the second youngest value should be regarded with circumspection

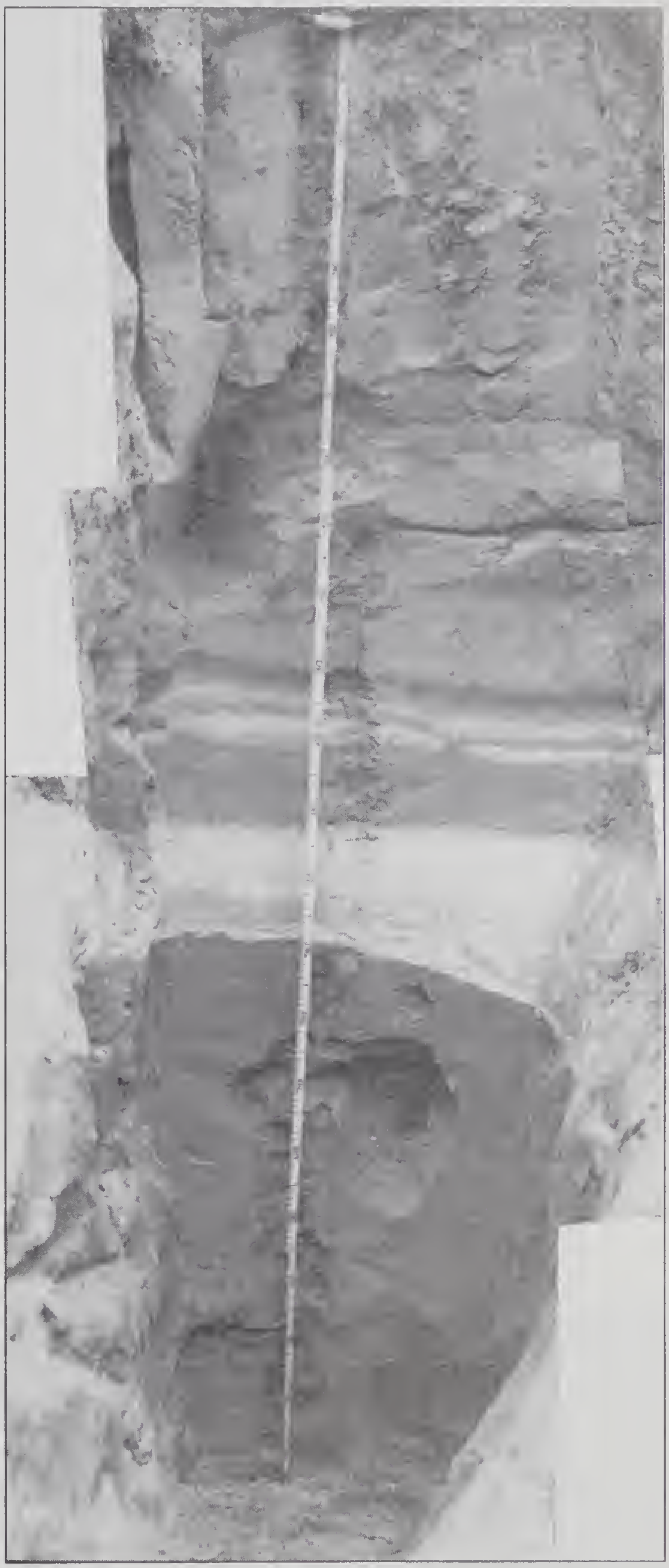


Figure 22. *Photo mosaic of Fort Selkirk tephra and surrounding fine silty sand. Tephra and surrounding sand are magnetically reversed. Normally magnetized sand occurs near the upper part of field of view. Photograph by L.E. Jackson, Jr. GSC 1999-012G*

because it partly overlaps with the Cobb Mountain Subchron (Mankinen and Dalrymple, 1979; Shackleton et al., 1990; Cande and Kent, 1995; Jackson et al., 1996a).

In conclusion, the magnetically normal part of the Fort Selkirk interglacial sediments can be no younger than Jaramillo Subchron (1.07–0.99 Ma) and as old as the Cobb Mountain Subchron (ca. 1.2 Ma). The magnetically reversed part of the succession predates these ranges. However, the lack of evidence of erosional unconformities or weathering between the sediments of opposite polarity suggests that deposition of the normal sediments closely succeeded deposition of the reversed sediments in time.

Younger pre-Reid till (subsurface) and outwash (units $G^{PR}p$, $G^{PR}t$)

Diamicton units identified as till, because of their content of faceted and striated clasts, were observed in placer mines and exploratory trenches in the Nansen Creek basin and the upper Klaza River in the Dawson Range (section 4, Map 1876A; LeBarge, 1995). This corroborates similar observations by Cairns (1915) and Bostock (1936). These tills are capped by weathered cobble gravels in Discovery Creek and elsewhere in the Nansen Creek basin (LeBarge, 1995). The Wounded Moose paleosol is commonly present in the upper 1–2 m of these gravel units (*see* 'Soils' in 'Physiographic setting'). Most micaceous and granitic clasts within the soil are disaggregated and are partly weathered to clay. Clasts have prominent clay skins coating them. The outwash gravels are also commonly cut by sand wedges, periglacial features characteristic of extremely cold and arid environments (Péwé, 1959). Both till and outwash are buried beneath widespread colluvium which blankets hillsides in this region.

Weathered outwash gravels without associated till are discontinuously present along the north side of the Big Creek valley up to the divide with Bow Creek where former pre-Reid meltwater channels are apparent at approximately 1100 m elevation. With few exceptions, these gravel beds and pre-Reid till units noted at the upper Nansen Creek and Klaza River basins only contain lithologies from the Dawson Range (Fig. 18H). Thus, the glacial ice present in the upper parts of the Nansen Creek, Big Creek, and Klaza River basins originated from ice centres within Dawson Range (LeBarge, 1995).

Pre-Reid glaciofluvial sand and gravel units are commonly cut near the surface by ice-wedge pseudomorphs and sand wedges (Fig. 23). The former are filled with sediments that slumped into cavities created by the melting of ice wedges whereas the latter are contraction fissures filled with wind-blown sand (Fuller and Hughes, 1987). Pre-Reid glaciofluvial gravel beds are deeply weathered to more than 1 m below their surfaces. The reddish-brown colour, clay skins around pebbles, and weathering of felspathic stones to clay make the pre-Reid outwash highly distinctive (Smith et al., 1986).

Age

These sediments are assigned to the younger of the pre-Reid glaciations because of their location well beyond the limit of deposits of the next youngest (Reid) glaciation, the lack of any overlying glacial deposits, and the development of the Wounded Moose paleosol on them.

Pre-Reid–Reid interglacial period

The interval between the younger pre-Reid glaciation and the Reid Glaciation is estimated at a minimum of about 600 ka. This figure is arrived at by using the last magnetic reversal (ca. 780 ka BP) as a limiting age for the younger pre-Reid glaciation and fission track and thermoluminescence ages on the Old Crow and Sheep Creek tephra units that overlie sediments deposited during the Reid Glaciation and correlative Delta Glaciation elsewhere in Yukon Territory and Alaska. Ages for these tephra units are in the 140 ka and 190 ka range, respectively (Westgate, 1989; Berger et al., 1996). Sediments deposited during the long pre-Reid–Reid interval have been noted at only three locations. They are detailed below. The first two occurrences likely were deposited immediately prior to the Reid Glaciation. Only the Pony Creek core sediments and the Wounded Moose paleosol, which marks a dramatically warmer and wetter climatic period, span a significant

Figure 23.

Wounded Moose soil cut by sand wedges (denoted by lines), near Pelly ranch. Soil colours range from 5YR 6/6 to 5YR 6/8 up to 2 m below the surface. Photograph by L.E. Jackson, Jr. GSC 1999-012H portion of this period (section 3, Map 1876A; section 5, Map 1877A; *see also* 'Soils' in 'Physiographic setting'). The term Wounded Moose has been and is applied to paleosols beyond the Reid glacial limit having physical and chemical characteristics falling within the range of the paleosols studied by Smith et al. (1986). It is quite possible that similar soils could have formed at different times i.e. between and following pre-Reid glaciations. In this paper, the term is applied to paleosols that have the characteristics described by Smith et al. (1986) and clearly postdate the youngest pre-Reid glaciation.

Bradens Canyon sediments (subsurface)

Stratified sand, gravel, and crossbedded sand separated by fine organic detritus underlie the Reid Till at Bradens Canyon along Pelly River (Ward, 1989, 1993; section 2, Map 1878A; Fig. 17, 1878A-2). The sediments are fluvial in origin, presumably deposited by Pelly River. The organic detritus and underlying interbedded sand and gravel are cut by ice-wedge pseudomorphs indicating that a periglacial climate was present at the time of deposition. The entire sequence is faulted and folded due to overriding by glacial ice during the Reid Glaciation.

Victoria Creek basal gravel (subsurface)

Victoria Creek basin, along the southern margin of the map area, was last glaciated during the pre-Reid glaciations. Victoria Creek has eroded through up to 16 m of sand and gravel fill (section 2, Map 1876A). The upper 10 m of fill is angular to subangular gravel that contains ventifacted clasts, often wind-sculpted on several sides. It has been assigned to the unit $A^{R}t$. This gravel was graded to the edge of the Cordilleran Ice Sheet along the southern margin of the Dawson Range (immediately south of the Carmacks map area) during the Reid Glaciation. It was deposited under extremely severe climatic conditions (Jackson, 1993). This unit is underlain by more than 5 m of subangular to rounded manganese-stained pebble gravel that lacks any ventifacts. There is a 1 m thick transition zone between the lower mature gravel and upper ventifact-rich gravel. The more mature lower gravel was apparently laid down by Victoria Creek prior to the onset of the Reid Glaciation.

Pony Creek meltwater channel sedimentary fill (subsurface)

A sedimentary fill within a 20 m deep meltwater channel was fortuitously cored (Archer-Cathro DDH-115) during exploratory drilling for gold in 1988 in the basin of Pony Creek, a tributary to Victoria Creek (Fig. 1; section 3, Map 1876A; Fig. 24). The Victoria Creek basin lies beyond the limit of ice cover during Reid Glaciation. It was last glaciated during the pre-Reid glaciations and the meltwater channel was cut at that time. Twenty-one metres of continuous core (drilled at a 45° angle) was obtained starting 8.75 m below the surface. The core contains alternating thick intervals of stony colluvial diamicton derived from local bedrock, thin silt and sand beds, and a few thin peaty beds. The diamicton units range from unoxidized to oxidized. The oxidation is the result of extensive pedogenesis. Analysis and interpretation of these buried soils are detailed in Jackson et al. (in press) and in Appendix A. These buried soils are complete from A-horizon to parent material (C-horizon). All are classified as podzols based upon the Canadian System of Soil Classification (Soil Classification Working Group, 1998). Podzols form only under conditions characterized by mean annual temperatures more than 0°C and moist climatic conditions. The nearest locations where analogous contemporary conditions can be found is the Pacific Coast or moist montane sites hundreds of kilometres to the south. Assuming such conditions, the soils would have required a period of time comparable to the present Holocene interglaciation (10^{4} a) to have formed. The two lowest soils are the thickest and are separated by stony, unoxidized colluvial diamicton. The upper two soils are thinner and closely

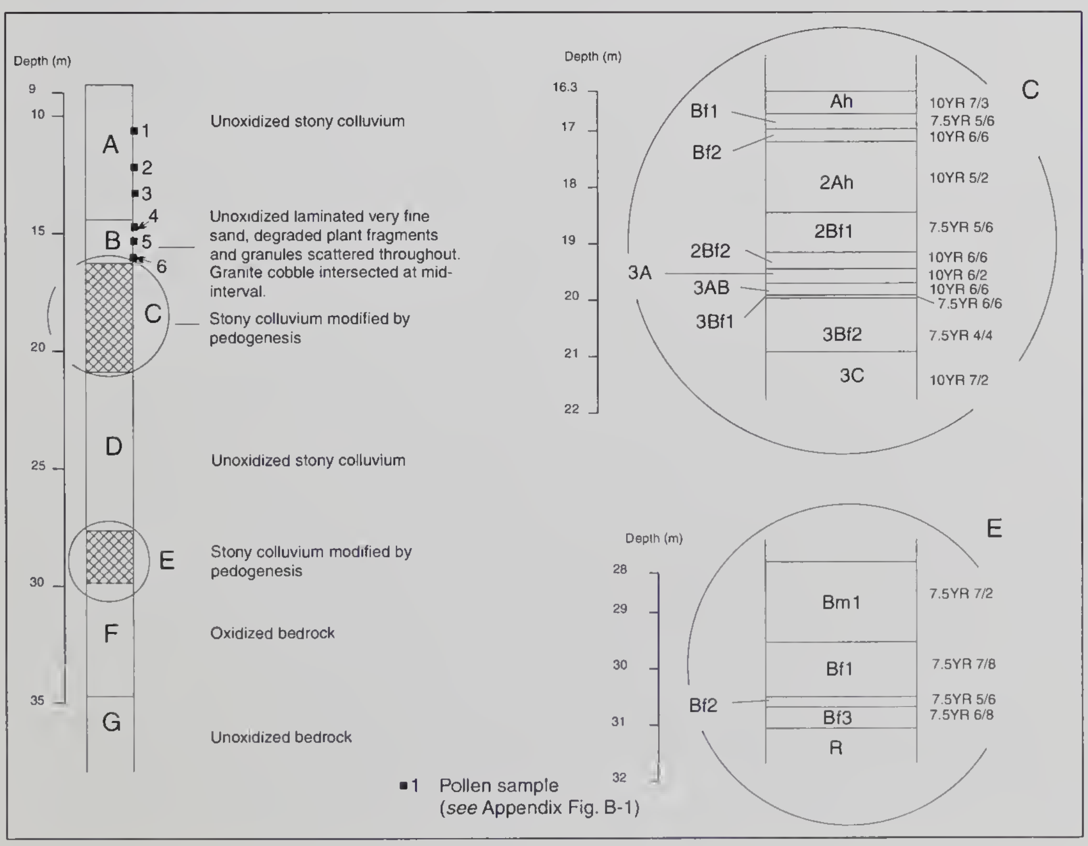


Figure 24.

Schematic representation of the Pony Creek core with details of buried soil horizons (cross-hatched areas). Pollen samples are summarized in Appendix A.

spaced and may have formed during a single period of interglacial climate. In addition to buried soils, fossil pollen has been recovered from unoxidized colluvial diamicton and interstratified lacustrine sediments above the buried soils (Fig. 24). Pollen recovered from diamicton is dominated by herb, shrub, and grass palynomorphs indicative of a shrub-herb tundra environment (Jackson et al., in press; Appendix B). Underlying finer sediments containing plant material yielded pollen indicative of an open spruce forest, which exists in the area at present (Appendix B).

The sedimentary fill is interpreted as having accumulated during alternating glacial and interglacial or interstadial cycles; colluvial diamicton units accumulated within the meltwater channel during periods of seasonal thaw during an overall glacial climatic regime. Conversely, the buried soils formed and pond sediments accumulated during interglacial or interstadial periods.

It is not clear whether the formation of the upper three soils and deposition of pond sediments occurred during separate or during a single interglacial period. The upper 8 m of this core (drilled at 45°) was not recovered. The surface soil in the area is correlated to the Diversion Creek paleosol (*see* below). Consequently, the uppermost colluvial unit (unit A) could be no younger that the Reid Glaciation. Therefore, the underlying soils and pond sediments represent at least two and as many as four glacial and interglacial cycles between the pre-Reid and Reid glaciations (Fig. 17).

Reid Glaciation sediments

Drift deposited during the Reid Glaciation is eroded and patchy outside major valleys and terminal moraines have been largely removed by erosion or buried by eolian deposits. This has made determination of the limits of glacial cover during the Reid Glaciation difficult in many areas (Fig. 3). The degree of erosion of these sediments corroborates an age predating ca. 190 ka BP for this glaciation.

Till blanket (unit $M^{R}b$) and till veneer (unit $M^{R}v$)

Till deposited during the Reid Glaciation generally forms patchy blankets or veneers over upland areas. It is texturally similar to till deposited during McConnell Glaciation. The limit of glacial cover during the Reid Glaciation terminates along a discontinuous digitate limit defined by former meltwater channels in the Dawson Range and Yukon River valley and ice-stagnation complexes in the Pelly River valley. The few natural exposures of till deposited during Reid Glaciation occur along cliff bank exposures in these areas (section 2, Map 1878A). End moraines are very subdued where they are preserved at all. The upper limits of Reid Glaciation deposits and landforms decrease from approximately 1040 m in the highlands along the eastern edge of the Carmacks map area and the eastern slopes of the Dawson Range to 490 m at its northwestern limit in the Yukon River valley at the confluence of the Yukon and Pelly rivers.

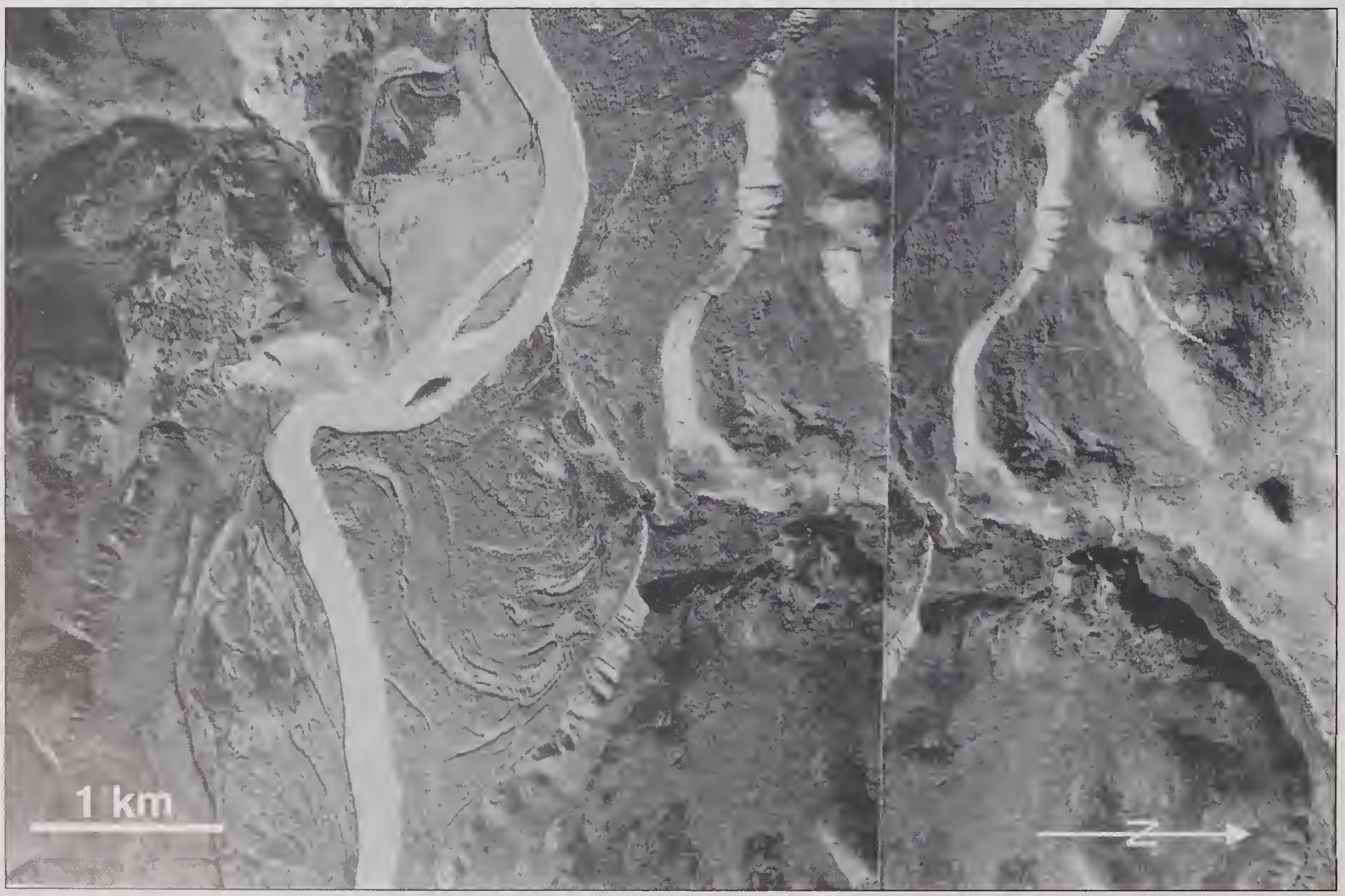


Figure 25. Reid Glaciation outwash terraces, Pelly River. NAPL A12259-193, -194

Glaciofluvial gravels (units G^Rt, G^Rp), Reid Glaciation

Reid glaciofluvial gravel is up to 50 m or more thick in the Yukon and Pelly river valleys where they have been incised into flights of terraces (unit G^Rt) which can be traced from the Reid limit to the western limit of the map area along Yukon River (Fig. 25). Elsewhere, undissected gravels with estimated thicknesses of up to tens of metres (unit G^Rp) commonly fill valleys within the Reid limit. Exposures of gravel are rare but texture ranges from massive, disorganized bouldery gravel at the glacial margin to horizontally stratified cobble and pebble gravel with distance from the margins. The upper one or two metres of gravel commonly contain fossil periglacial structures formed during the subsequent McConnell Glaciation including involutions and ice-wedge pseudomorphs.

Alluvial sediments contemporaneous with Reid Glaciation (units A^Rt, A^Rf, A^Rx)

These sediments include gravel and coarse sand of nonglacial origin deposited in response to glacially induced, base-level changes and climatic change during Reid Glaciation (Jackson, 1993; LeBarge, 1995). They exceed 1 m in thickness and locally exceed 10 m. These sediments occur most extensively along tributaries to the upper Nisling River such as Victoria, Nansen, and Lonely creeks (section 2, 5, 7, Map 1876A; Fig. 26). Lithology and physical appearance of these sediments allow easy discrimination from outwash (valley train) gravels. Excluding rare erratics reworked from pre-Reid drift, these sediments contain only lithologies from the local drainage basin. In contrast, outwash contains lithologies external to the basin. Chert is the most diagnostic of these (Fig. 27). Furthermore, nonglacial gravels are angular to subangular and contain wind-sculpted (ventifacted) clasts. These are commonly ventifacted on several sides (Fig. 26). Ice-wedge pseudomorphs, the sediment-filled cavities formerly filled by an ice wedge, are common in these sediments. The nonglacial sediments commonly alternate between angular gravel and coarse sand at individual exposures and become increasingly sandy in texture over a few kilometres with distance from uplands. In contrast, outwash (valley train) sediments are dominated by coarse, subangular to subrounded unventifacted gravel which typically shows few textural changes over tens of kilometres beyond the glacial margin.

Jackson (1993) and LeBarge (1995) attributed the deposition of these sand and gravel fills to accelerated erosion of the Dawson Range due to the denudation of vegetation caused by the onset of the Reid Glaciation and establishment of a local base level determined by the digitate terminus of the Cordilleran Ice Sheet at the time of Reid Glaciation. Geurts and Dewez (1993) presented evidence to support the former existence of an extensive lake, ponded by the Cordilleran Ice Sheet of Reid age along the southern margin of the Dawson Range. They concluded that this lake flooded much of the valley of Lonely Creek and spilled into the Klaza River basin (Fig. 3, map C). Although stratigraphic evidence supporting this conclusion is limited, many of the fan-shaped landforms that occur along the Lonely Creek valley and gravel and sand fills in the Victoria Creek and Nansen Creek valleys may represent former deltas that were graded to stages of this lake. Further studies of the sedimentary fills in the Lonely Creek valley will be required to conclusively demonstrate whether or not this lake existed. Presently, few exposures of sedimentary fills exist in the valley of Lonely Creek or its tributaries.

Pre-McConnell Glaciation sediments (undivided)

Undivided alluvial deposits of pre-McConnell age (units A_t^u, A_x^u)

This unit includes uncorrelated alluvial terrace gravels (A_t^u) and a complex of organic and inorganic sediments (A_x^u) filling the bottoms of steep-sided, first- and second-order stream valleys beyond the limit of the McConnell Glaciation. Placer mine excavations reveal the valley fill complex to include colluvium soliflucted from adjacent slopes, angular to subrounded gravel derived from the erosion of adjacent colluvial or glacial sediments, sand and gravel of the local trunk stream, and small alluvial fans and interstratified organic and inorganic silts, buried bog, and eolian sediments (section 8, Map 1876A).

Figure 26.

Frost-shattered and ventifacted alluvial gravel and micaceous sand deposited during Reid Glaciation, headwaters, Nisling River. Clasts and sand are entirely derived from local mica schist units. Photograph by L.E. Jackson, Jr. GSC 1999-012I

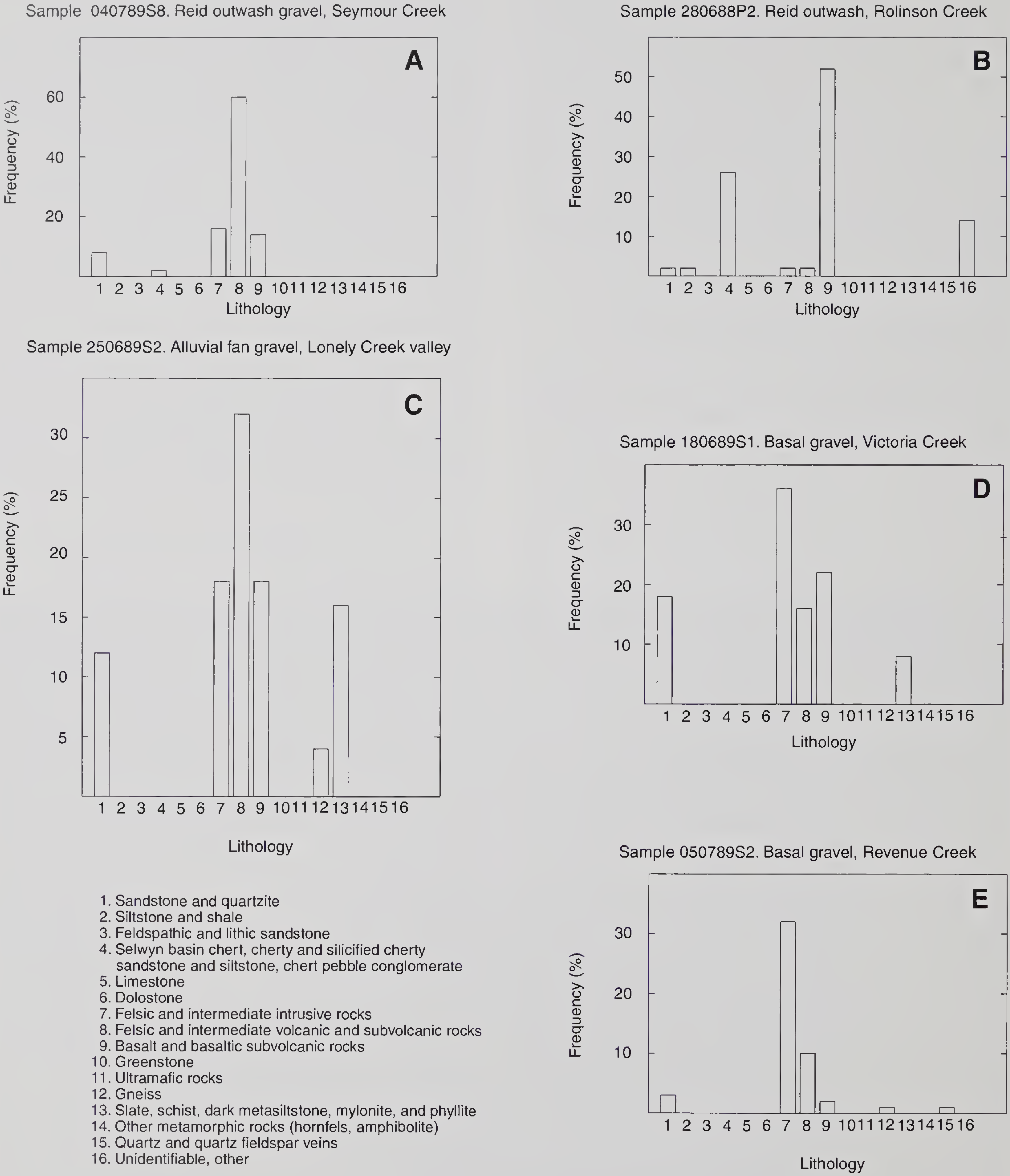


Figure 27. *Lithologies in nonglacial fluvial gravel, Lonely Creek, Victoria Creek, and Revenue Creek contrasted with nearby deposits of glacial outwash gravels of Reid and McConnell age.*

Sediments filling valleys within the area covered by ice during the Reid Glaciation may range in age from the end of Reid Glaciation to the present. Those beyond the limit of drift are undated. Consequently they may have been deposited during the Reid Glaciation or predate it in part.

Reid–McConnell interglacial period sediments

The interval between the end of the Reid Glaciation and the onset of the McConnell Glaciation encompasses at least 160 ka from before ca. 190 ka to 30 ka BP. This includes the last (Sangamonian) interglacial and the early and middle Wisconsinan (isotope stages 5e to 3; Hughes, 1989). The most common horizon from this period is the Diversion Creek paleosol (*see* 'Soils' in 'Physiographic setting'). This formed during a part or parts of the Reid–McConnell interglacial when the climate was comparable to that of the present. The Diversion Creek soil has been correlated to the Sangaman soil in the midwestern United States (Smith et al., 1986; Tarnocai, 1989). The Diversion Creek paleosol is commonly found developed on Reid Glaciation outwash or on eolian fine sand or silt. It is commonly buried beneath eolian sediments deposited during the McConnell Glaciation.

Sediments deposited during the Reid–McConnell interglacial period are apparently common within alluvial sequences beyond the limit of ice cover during McConnell glaciations (*see* previous section) but are difficult to document because most of the Reid–McConnell interval is beyond the limit of radiocarbon dating and few widespread stratigraphic units exist that allow relative dating control. Sediments that undoubtably date from this period are exposed at Granite Canyon and Revenue Creek (Ward, 1989, 1993; Jackson et al., 1990, 1996b).

Granite Canyon sediments (subsurface)

A 3.5 m thick fining-up sequence of interstratified gravel, sand, and silt underlying sediments of McConnell Glaciation age at the mouth of Granite Canyon along the Pelly River (section 1, Map 1878A) has been described by Ward (1993). Organic beds from the top of this sequence have yielded a rich record of insect remains and plentiful pollen along with two radiocarbon dates of 36 060 ± 2000 BP (AECV 1422C) and 37 120 ± 350 BP (TO-1278). Because these dates were determined using the accelerator mass spectrometer (AMS) method, they should be prudently regarded as minimum ages. The fining-up sequence of these sediments, inclusion of organic beds, and their location close to the contemporary surface of the Pelly River in the middle of the Pelly River valley, suggest that they are vertical accretion floodplain deposits or interfan sediments.

Paleoenvironmental interpretations

Analysis of organic-bearing beds within this section has yielded proxy paleoenvironmental information which indicates that a boreal forest covered the area during the middle Wisconsinan:

> "The insect assemblage includes several genera of bark beetles and planthoppers and appears to indicate the presence of forest, although plant macrofossils are lacking. Also, ground beetles in these sediments are found today south of tree line, and ants extend only slightly beyond tree line today. As well, the sample lacks fossils that are found only in tundra regions. The pollen assemblage...(is) dominated by spruce, also indicating forested conditions, likely a boggy/muskeg community consisting of black spruce and sedge..." (Ward, 1993, p. 114).

Pelly ranch sediments (subsurface)

Cryoturbated pebbly sand clearly deposited during the Reid–McConnell interglacial period occurs at the top of a high outwash terrace approximately 7 km upstream from Pelly ranch on the north side of Pelly River. The sand is an alluvial fan deposit, 0–4.5 m thick, that unconformably overlies the Diversion Creek paleosol which has developed in Reid Glaciation outwash and is in turn overlain by eolian silt deposited during McConnell Glaciation. The contacts with the underlying paleosol and overlying eolian silt are marked by numerous ventifacted pebbles. This pebbly sand has yielded fragmental remains of a large ungulate, possibly *Bison* sp. (R. Harington, written comm., 1988).

Revenue Creek sediments

Revenue Creek flows northward into Big Creek through a steep-sided valley. It lies beyond the limits of glacial ice cover during the Reid and McConnell glaciations. Placer mining has exposed up to 11 m of sedimentary fill consisting of organic-rich silt, silty peat, gravel, and sand (section 1, Map 1876A). This succession overlies bedrock or a weathered auriferous gravel that overlies weathered bedrock. The basal auriferous gravel is composed almost entirely of schistose clasts from the present drainage basin. However, large glacial erratics (granitic) over 1 m across occur as a lag at the base of this gravel indicating that the basin was glaciated during the pre-Reid glaciations. Paleomagnetic investigation of these sediments indicates that they were deposited during the present geopolarity interval (Bruhnes Chron) and consequently are younger than ca. 780 ka. Logs near the surface of the fill at the same location proved to be beyond the range of radiocarbon dating with ages of more than 38 000 BP (GSC-4963) and more than 40 000 BP (GSC-4935). The sedimentary fill at the downstream and upstream ends of the placer mine (less than 1 km apart), were sampled for fossil pollen and plant and insect macrofossil material. These were analyzed by H. Jetté and A. Telka of the Paleoecology section of Terrain Sciences Division, Geological Survey of Canada (Appendices C–E). The two sections have yielded distinct paleoenvironmental records. These are detailed in Figure 28 (in pocket). Sediment at both the sections accumulated prior to the McConnell Glaciation based upon conventional and accelerator mass spectrometer ^{14}C ages determined on samples from near the surface. The 44 980 ± 1200 BP age from the upstream section is regarded as being nonfinite.

During the Reid Glaciation, a tongue of the Cordilleran Ice Sheet pressed up Big Creek to no more than 15 km below the confluence of Big Creek and Seymour Creek (*see* location inset, Fig. 28) and to no less than 610 m elevation raising the local base level approximately 150 m. This increase in base level may in part have caused the aggradation that preserved the record of climatic change in the Revenue Creek valley. If the correlation of zone 3 (downstream section) to the Reid Glaciation is correct, the sediments of Revenue Creek contain a record of interglacial–glacial–interglacial periods and their transitions which predate isotope stage 5. A detailed mapping of Revenue Creek valley along with a more detailed paleoenvironmental study will be required to clarify correlations.

McConnell Glaciation sediments

The McConnell Glaciation (Bostock, 1966) was the last regional glaciation of Yukon Territory (Bostock, 1966). It is late Wisconsinan (Jackson and Harington, 1991; Jackson et al., 1991). Sediments deposited during this glaciation typically underlie

Figure 29. Terrain streamlined by the passage of ice during the McConnell Glaciation. NAPL A11069-76

the surface east of the limit of McConnell glacial cover and in major valleys west of it where valley train deposition filled them with sand and gravel.

Till blanket (unit Mb**) and till veneer (unit** Mv)

Till blankets and veneers deposited during the McConnell Glaciation (units Mb, Mv) commonly overlie bedrock on the sides of mountain valleys and low-relief plateau elements (Fig. 29). Till blankets grade into till veneers with slope steepness and elevation. Till veneers and blankets are commonly resedimented and grade into colluvium on steep slopes. Morainal blankets locally overlie other Quaternary sediments in major valleys such as the Yukon River valley. Till also forms prominent lateral and end moraines particularly where the margin of the Cordilleran Ice Sheet of the McConnell Glaciation pushed up valleys such as those of Nansen and Crossing creeks along the eastern margin of the Dawson Range.

Glaciofluvial plain and channel sediments (unit Gp)

Coarse gravel, sand, and minor silt deposited along former glacial stream courses distal (removed) from glacial ice margins. Internal structure is typically massive to thickly bedded gravel near the surface but these sediments may increasingly contain ice-collapse structures with depth reflecting progressive change from a proximal to distal sedimentary environment during depositional history. Thicknesses may range from a veneer to many tens of metres where sediments fill valley floors or former meltwater channels.

Glaciofluvial terrace sediments (unit Gt)

These include gravel, sand, minor silt, and diamicton cut by flights of terraces. The sediments beneath terrace surfaces that were deposited during terrace cutting may be as little as 1 m thick. They commonly overlie glaciofluvial valley fills or glaciofluvial deltas 10 m or more in thickness. McConnell (Gt) and Reid ($G^{R}t$) glaciofluvial terrace sediments are distinguished by tracing them upstream to features marking former McConnell or Reid ice margins.

Glaciofluvial complex (unit Gx)

Gravel, sand, and diamicton form complexes of terrace, knob and kettle, and esker ridges (Fig. 9). Stratification and textures are quite variable ranging from ripple-bedded, fine sand and rhythmically bedded silt and clay in the deposits of former ice-walled lakes to massive coarse gravel. Stratification is frequently distorted and faulted due to syndepositional and postdepositional ice collapse. These complexes are particularly abundant in valleys at the McConnell Glaciation limit such as in the Yukon River valley in and around Carmacks (Map 1879A).

Discontinuous glaciofluvial sediments (unit Gu)

This unit is characterized by interspersed hummocky deposits of gravel and sand and minor silt, usually less than 5 m thick and units of Mb and Mv which may comprise up to 50% of the unit. This unit typically occurs in upland areas. It indicates sedimentation from stagnant ice but without the greater concentrations of sediment involved in the deposition of unit Gx deposits.

Glaciolacustrine plain sediments (unit Lp)

Glaciolacustrine sediments commonly consist of rhythmically bedded, fine sand and silt and minor clay. Thickness of deposits is commonly 5 m or more (Fig. 10). Bedding is locally complicated by syndepositional slumping and dropstones. Surface topography is flat to rolling except where sediments have been modified by erosion. These sediments commonly contain extensive lenses of clear ice. Thermokarst features develop where ice lenses melt.

Glaciolacustrine blanket (unit Lb**) and glaciolacustrine veneer (unit** Lv**) sediments**

Silt, fine sand, and minor clay thin enough to conform to underlying topography make up these units. They usually represent the margins of thicker and more extensive unit Lp deposits.

Glaciolacustrine complex (unit Lx)

In this unit sand, silt, gravel, and diamicton underlie a hummocky ridged and pitted surface. Stratification ranges from massive to thinly and rhythmically bedded and it has been extensively disrupted by syndepositional slumping. Strata are lensoidal and usually difficult to trace for more than 10 m. This unit represents glaciolacustrine sediments laid down adjacent to an ice margin with sediments being deposited from suspension, glaciofluvial streams flowing off of and beneath glacial ice and adjacent emergent terrain, sediment gravity flow (debris flow) from ice and emergent terrain, and deposition from icebergs.

Late McConnell Glaciation and postglacial sediments

Eolian sediments (unit Eb)

Complexes of barchan and parabolic dunes were deposited during the McConnell Glaciation and were active into the early postglacial (Fig. 30). Dunes may have reliefs up to 10 m.

Eolian veneer (denoted by a symbol on the maps)

Eolian veneer is a discontinuous covering of fine sand and silt. It includes the White River tephra over the southern two-thirds of the map area.

Floodplain sediments (unit Ap)

This unit is defined by gravel and sand, more than 1 m thick, with minor to extensive lacustrine fine sand and organic sediments which are subject to inundation during summer and spring ice-jam flooding. Sediments are horizontally stratified. The fine sediment component is the result of deposition in abandoned channels (oxbow lakes) and backswamps (swamp areas along the margins of floodplains).

Alluvial terrace sediments (unit At)

Flat-lying gravel and sand with minor silt, more than 1 m thick, make up this unit. Stream terraces are remnants of older floodplains out of reach of flooding because of stream incision. Except for the lowest terraces, unit At sediments are predominately horizontally massive to planar stratified to trough cross-bedded, clast-supported gravels indicative of sedimentation in a braided stream environment. This contrasts with meandering stream-sedimentary environments that predominate along contemporary streams.

Alluvial fans (unit Af)

Features classified as alluvial fans include a spectrum of landforms ranging from fans that receive only fluvially deposited sediments, to those that receive a significant component of debris flow and avalanche-borne sediment. This classification is used because the discrimination of alluvial fans from colluvial fans is arbitrary and based upon the extent of fluvial activity versus avalanche and debris-flow activity perceived on the fan surface from airphoto interpretation. Fans with

Figure 30. Dune field near Ne Ch'e Ddhäwa volcanic edifice. NAPL A12183-196

surface slopes less than 15° and without surface indications of snow or rock avalanche or debris flow deposition were mapped as alluvial fans.

Alluvial fan sediments are predominantly gravel and diamicton. Sorting usually becomes increasingly poor as fans become more debris-flow and avalanche dominated. Evidence from comparable montane terrain in the Rocky Mountains of Alberta and British Columbia suggests that the debris flow component of fans usually increases with increasing fan gradients and increasing ratios of basin relief to basin area (Jackson, 1987; Jackson et al., 1987). The past presence or absence of debris-flow activity on a fan involves the investigation of many textural and geomorphic parameters and features (*see* Jackson, 1987).

Colluvial blanket (unit Cb) and colluvial veneer (unit Cv) sediments

Colluvium is stony to bouldery diamicton produced by the predominantly physical breakdown of bedrock and reworking transportation by solifluction. It locally includes reworked glacial sediments. Colluvial blanket and veneer sediments are included with postglacial sediments but beyond the limit of ice cover during the McConnell Glaciation, they may represent tens of thousands or hundreds of thousands of years of transport and accumulation. They are the most extensive map units in the Carmacks map area. Beyond the limits of deposits laid down during the Reid Glaciation, transport of colluvium from upper hill slopes by solifluction has buried the pre-existing landscape in a manner similar to the way that wax flowing down the side of a candle buries its original surface. Underlying deposits include deposits and landforms from the pre-Reid glaciations and auriferous placer deposits.

Colluvial apron sediments (unit Ca)

Bouldery diamicton, poorly sorted sand, and gravel beds, form a wedge-like slope-toe complex of coalesced fans dominated by avalanche, debris flow, and solifluction. Although fluvial processes do deposit and redeposit these sediments to some degree, they play a secondary role to nonfluvial gravitational processes and their deposits dominate. However, with increasing drainage area, colluvial fans grade progressively into alluvial fans. Slopes range from less than 10° near the slope toe to more than 30°. Thickness ranges from nothing along the upper edge to 10 m or more along the toe.

Rockfall deposits (unit bCa)

Rockfall deposits (talus) are metastable accumulations of angular bouldery debris resting at the angle of repose which ranges from approximately 30° to 40°. Thickness ranges from 0 at the upper margin to 10 m or more along the base.

Bog, fen, and swamp deposits (unit O)

Accumulations of peat and minor organic sediments are sufficiently thick (usually 2–3 m) to mask the morphology of underlying deposits (Fig. 15, 16). Blanket bog thin enough (usually less that 2 m) to conform to the contours of underlying sediments is denoted by a pattern. Organic sediments beyond the limit of the McConnell Glaciation contain variable amounts of eolian silts and sands.

LATE TERTIARY AND QUATERNARY HISTORY

The succession and stratigraphy of sediments and interstratified volcanic rocks described in the previous sections and analysis of the fossil pollen, plants, faunal remains, and paleosols described in the previous sections permit a reconstruction of geological events since the early Pleistocene in the Carmacks map area. These can be supplemented by data from adjacent areas of Yukon Territory to further detail events since the late Tertiary Period.

Late Tertiary–early Pleistocene

Yukon Territory enjoyed a much milder climate until the onset of periodic glaciation in the late Pliocene (Tarnocai and Valentine, 1989; Tarnocai and Schweger, 1991). During the Pliocene, vegetation and soils existed in the Old Crow area (contemporary mean annual temperature and precipitation -10.1°C and 214 mm respectively) which are presently found no farther north than central British Columbia (contemporary mean annual temperature and precipitation 4°C and 550 mm respectively; Drumke, 1964; Atmospheric Environment Service, 1982a, b; Tarnocai and Schweger, 1991). The preglacial climate of the Carmacks map area, 6° of latitude south of the Old Crow region, can be assumed to have been as mild or milder than that of the Old Crow area. Such a climate persisting over hundreds of thousands or millions of years almost certainly resulted in deeply weathered mantle over the central Yukon Territory including the Carmacks map area. The auriferous White Channel Gravel in the Klondike district (McConnell, 1908) was deposited during this period. The quartzose composition of this unit, from which its colour and name are derived, reflect a climate warm and wet enough for chemical weathering to eliminate less chemically resistant mineralogies (Boyle, 1979, p. 356). This warmer and wetter climate ended in the late Pliocene with marked climatic cooling. The deposition of the quartzose White Channel Gravel was succeeded by polylithological gravel thought to be outwash during the late Gauss Chron (>2.6 Ma) in the Dawson area (Froese et al., 1997). These events apparently significantly predate glacial deposits present in the Carmacks map area. Only the reversal of flow of Yukon River from southeast to northwest can be cited as possible evidence of regional glaciation prior to the older pre-Reid glaciation in the Carmacks map area. This change in flow direction was in place by the first eruption of the Selkirk volcanics ca. 1.6 Ma and prior to the start of the older of the two pre-Reid glaciations for which a sedimentological record exists in the Carmacks map area (Fig. 3A). By this time, the Yukon River was flowing at approximately the same level as it does today. Furthermore, the Pelly River, which was also filled by Selkirk basalt, had presumably come into being and had assumed its contemporary east to west course across and a hundred metres below the southwest-trending preglacial valley now occupied by Von Wilczek, Łütsaw, and Tthe Ndu lakes and the underfit Von Wilczek and Willow creeks (Fig. 3A).

Early glaciation is also suspected in the diversion of the headwaters of the Klaza River across the Dawson Range. However, the relatively narrow valley of the Klaza River west of the diversion (Fig. 3) (near the confluence of False Teeth Creek) and the presence of fresh and unweathered gravel on terraces within the valley suggest that the diversion became permanent relatively late in the Pleistocene.

Pre-Reid glaciations

Only general events can be reconstructed from the pre-Reid glaciations and almost all reconstructions are related to the youngest of these glaciations which was accompanied by the eruption of basalt in the Fort Selkirk area. Ice must have covered most of the map area. The regional descent of the Yukon Plateau from east to west would have caused the ice surface to descend in the same direction. Ice reached an elevation of at least 945 m along western margin of the map area (138°W) based on the upper limits of meltwater channels in that area (Fig. 3, Map B). Thus, ice thickness over the Yukon River valley at the western margin of the map area was at least 550 m. Exhaustive searches for the upper limits of erratics were not carried out as part of this study. Future investigations of the distribution of high-level erratics may further clarify the extent of ice cover during the pre-Reid glaciations.

Ice advanced from the east and south into the map area and interacted with glaciers from independent ice centres in the Dawson Range. Degraded cirques and scattered arête ridges in the Dawson Range are relict features from pre-Reid glaciations. It was during one of the pre-Reid glaciations that the headwaters of the ancestral Klaza River, which formerly drained south through the valley of Lonely Creek, were first diverted across the Dawson Range creating the contemporary underfit Lonely Creek (Bostock, 1936; Hughes, 1990; Fig. 3).

The dramatically greater extent of the pre-Reid glaciations as compared to the Reid and McConnell glaciations does not have an unequivocal explanation. This pattern of extensive early Pleistocene glaciations and less extensive late Pleistocene glaciations also occurs in the Brooks Range of Alaska where drift of early Pleistocene and late Pliocene ages (Gunsight Mountain and Anatuvuk River glaciations) lie well beyond the limits of late Pleistocene drift units (Hamilton, 1991). Precipitation patterns were the main controls on the distribution and extent of glaciers during the McConnell Glaciation and were likely so throughout the Quaternary (Jackson et al., 1991). It is possible that the tectonically active and geologically youthful Saint Elias and Alaska ranges may have been significantly lower during the late Pliocene–early Pleistocene allowing more moisture to reach the Yukon Territory interior (Jackson et al., 1991). Another source of moisture present during the pre-Reid era but lacking during the Reid and McConnell glaciations might have been the Arctic Ocean. Dramatic changes in flora, fauna, and sedimentation patterns were approximately coincident with the Matuyama/Bruhnes magnetic reversal (ca. 0.78 ka). It has been suggested that the Arctic Ocean may have had a significantly reduced or no permanent ice cover during intervals of the early Pleistocene and late Pliocene (Herman, 1970; Herman et al., 1971; Theide et al., 1990; Clark et al., 1990). However, the evidence is equivocal and the effect that an ice-free Arctic Ocean would have on precipitation in central Yukon Territory is not clear. Lastly, there is a growing body of evidence that early continental ice sheets were confined to eastern and central North America (Barendregt and Irving, 1998). If this is correct, then the large, high-pressure systems associated with continental ice sheets would have been centred farther east and they would have been less significant in deflecting moist air from the Pacific Ocean away from the interiors of Yukon Territory and Alaska.

Middle Pleistocene

The middle Pleistocene largely coincided with the estimated 600 ka interval between the pre-Reid and Reid glaciations. This was presumably a period of erosion and incision based upon the paucity of sediments dating from this period. Sedimentation within pre-Reid meltwater channels such as the one encountered by drilling at Pony Creek (section 3, Map 1876A; Fig. 24) yield the only extended sedimentary record for this period. The Wounded Moose paleosol formed under one or a succession of mild interglacial climates that alternated with glacial climates between the Reid and pre-Reid glaciations. The fill within a pre-Reid meltwater channel at Pony Creek site preserves podzolic soils that developed at 1000 m elevation in the Dawson Range. Conversely, periglacial climatic conditions occurred between these soil-forming periods during which the sterile colluvial layers that separate the soils were deposited. These cold periods are correlated to suspected regional glaciations. If sediments were deposited during these events in the Carmacks map area, they were obliterated by the subsequent Reid and McConnell glaciations or removed by erosion during interglacials. Evidence of glaciations during the pre-Reid–Reid interval apparently exists in the subsurface of southeastern Yukon Territory; Klassen (1987) carried out K-Ar dating of basalt flows interstratified with till in the Liard lowland. These ages fell within the pre-Reid–Reid interval.

This record of mid-Pleistocene glaciations is compatible with widely correlated proxy global paleoclimatic records constructed from deep-sea sediments (e.g. Shackleton and Opdyke, 1973) which suggest that the climate during the ca. 1.0–0.6 Ma period (roughly the interval between the younger pre-Reid and Reid glaciation) alternated between glacial and contemporary ones.

Reid Glaciation

The flow patterns of the Cordilleran Ice Sheet during the Reid Glaciation can only be reconstructed beyond the McConnell Glaciation limit. Based upon this, ice-flow patterns were probably similar to the subsequent McConnell Glaciation except for a greater ice thickness and extent. Ice advanced into the Carmacks map area from the Selwyn and Cassiar mountains to the east and southeast and from the eastern Coast Mountains from the south. The Cordilleran Ice Sheet pressed against the western and southern margins of the Dawson Range and advanced down the Yukon and Pelly river valleys into the area of confluence of the Yukon and Pelly rivers. The glacial climate largely denuded the uplands of vegetation. Treeline was depressed more than 850 m in the central Yukon Territory during McConnell Glaciation and the mean July temperature is estimated to have been 5° or less (Matthews et al., 1990). Loess and dunes were deposited extensively by katabatic winds. Assuming that the glacial interval recorded in the Revenue Creek downstream section (Fig. 28) represents the Reid Glaciation, forest and shrub vegetation was probably completely eliminated from the Dawson Range leaving only herb tundra. The resulting loss of vegetation from the land surface made denuded soil and weathered overburden available for erosion and transport and created new sediment sources under the intense physical weathering environment active during glaciation. This increased erosion rates and delivery of sediment to adjacent lowlands.

In the eastern Dawson Range, meltwaters from the ice sheet spilled across passes between Crossing Creek and Seymour Creek (S on Fig. 3C) and down the unnamed creek (U on Fig. 3C) which shares its low (945 m a.s.l.) divide with Merrice and Hoochekoo creeks (Bostock, 1936) and between Rowlinson Creek and upper reaches of Nisling River (N on Fig. 3C) farther south. Ice sheet encroachment into the eastern Dawson Range also raised base levels of streams flowing out of the Dawson Range by impoundment and diversion of these streams along ice margins. Aggradation of as much as 20 m occurred along streams draining nonglaciated basins such as Nansen Creek, Victoria Creek, Lonely Creek, and Klaza River. Local base levels were either determined directly by the Cordilleran Ice Sheet or by the elevation of large ice-ponded lakes as may have existed in the valley of Lonely Creek (L on Fig. 3C; Geurts and Dewez, 1993). Lacustrine sedimentation in the Lonely Creek valley and spillage of lake waters westward into the Klaza River basin (K on Fig. 3C) may have permanently diverted the headwaters of Klaza River across the Dawson Range at this time.

Lower Big Creek basin experienced aggradation due to an ice-margin-dictated increase in base level at the lower end of the basin and an input of outwash from another ice terminus higher in the basin (Fig. 3C; Map 1876A). A tongue of the Cordilleran Ice Sheet pushed up the Big Creek valley to no more than 15 km below the confluence of Big Creek and Seymour Creek (B on Fig. 3C) and no less than 610 m elevation raising the base level approximately 150 m. This caused up to 180 m of gravel to be deposited in the area of confluences of Seymour and Stoddart creeks with Big Creek. Terraces underlain by unweathered gravels at approximately 823 m on the ridge separating Seymour and Stoddard creeks near their confluences with Big Creek mark the top of this fill (area of UTM 382300, 6913400, Map 1876A).

Tributaries to Big Creek above the Seymour Creek confluence also aggraded in response to this significant aggradation (Jackson, 1993).

At the close of the Reid Glaciaition, outwash from the retreating Cordilleran Ice Sheet deposited thick gravel fills in the Yukon and Pelly river valleys which were subsequently incised into flights of terraces.

Reid–McConnell nonglacial interval

Little can be reconstructed of geological events during the more than 160 ka that separate the Reid and McConnell glaciations. This period encompassed the last (Sangamonian) interglacial and the early and middle Wisconsinan (isotope stages 5e to 3; Hughes, 1989). The Diversion Creek paleosol formed during the warmest interval of the last interglacial, presumably stage 5e. Climatic conditions were milder than those of the present during this soil-forming period. This warm interval is recognized widely in Yukon Territory and Alaska where it was accompanied by thawing of the permafrost and northern expansion of closed canopy spruce forest and related flora and fauna (Péwé, 1975; Schweger and Matthews, 1991). Zone 3 sediments in the Revenue Creek downstream section (Fig. 28) record closed-canopy forest at elevations higher than it occurs today in the Carmacks map area. On this basis, a tentative correlation with stage 5e is suggested for zone 3.

The sediments at the Granite Canyon section also fall within the Reid–McConnell period based upon accelerator mass spectometer radiocarbon ages. If these ages are truly finite, then they document the presence of closed canopy boreal forest in the area ca. 37 to 36 ka BP.

McConnell Glaciation

Jackson et al. (1991) have detailed the chronology of the onset of the McConnell Glaciation and the build-up of the Cordilleran Ice Sheet in central Yukon Territory. They concluded that, whereas expansive glaciers may have existed in mountainous areas of eastern Yukon Territory as early as 29 ka BP, montane valley glaciers did not advance into major valleys before ca. 26 ka BP and a full-bodied ice sheet did not come into being until after 23 ka BP.

In the Yukon Valley, the margin of the Cordilleran Ice Sheet extended to the area of the mouths of Williams and McGregor creeks and and pressed westward into Dawson Range (Fig. 3D; Map 1879A). Unlike the Reid Glaciation, meltwaters only crossed Dawson Range between Rowlinson Creek and Nisling River (N on Fig. 3D). This served to truncate and incise gravels at the confluences of Victoria and Nansen Creeks with Nisling River. The maximum advance of the Yukon River valley glacier was followed by recession and a readvance (section 1, Map 1879A). The limit of till deposited during this readvance is documented in Figure 10. Elsewhere, the Cordilleran Ice Sheet only reached the eastern margin of the map area.

Although it was beyond the limit of glacial ice, the Dawson Range was again denuded by the glacial climate. In addition, loess and sand, driven by katabatic winds, were deposited in fens and bogs forming muck deposits in valley and gulch bottoms.

Little absolute dating control exists to document the disappearance of the Cordilleran Ice Sheet in Yukon Territory. A radiocarbon age of 13 660 ± 180 BP (GSC-1110) was determined on organic-rich silt in lacustrine sediments in the terminus area of the St. Elias Mountains piedmont lobe complex in west-central Yukon Territory by Rampion (1971). This indicates that retreat from the terminal position had begun in this area before that time. Shell from marl 120 km inboard from the terminus of the Selwyn Lobe in the Pelly River basin yielded an age of 12 590 ±120 BP (TO-931; Ward, 1989) indicating extensive retreat by that time. This age must be regarded with caution because freshwater shells have been shown to provide unreliable radiocarbon ages because of the incorporation of dissolved inorganic carbon (Clague, 1982). Radiocarbon ages from the Continental Divide area of Selwyn Mountains indicate that ice had disappeared from that area by 9 ka BP (Jonasson et al., 1983; MacDonald, 1983).

Holocene events

Geological events in the Holocene were dominated by the adjustment of streams to nonglacial conditions. Streams formerly fed by the Cordilleran Ice Sheet such as the Yukon and Pelly rivers experienced a reduction of both discharge and sediment load with its disappearance. The result has been progressive incision by major streams and the cutting of terraces in McConnell Glaciation outwash. A similar pattern of incision is seen in steams draining areas that escaped glaciation during the McConnell Glaciation. In these basins, the revegetation by boreal forest and cessation of eolian sedimentation has apparently resulted in postglacial stream incision. The floodplain of Yukon River was close to its present level by 7000 a BP and only minor changes in its course have occurred since the eruption of the most recent White River tephra approximately 1230 a BP (Fuller, 1986).

Long-term temperature variation during the Holocene has resulted in periods of extensive permafrost degradation and expansion elsewhere in Yukon Territory (Burn et al., 1986; Burn, 1992). Periods of degradation during the early Holocene and the present century were particularly significant. These events probably affected the Carmacks area.

Volcano Mountain erupted in the early Holocene or near the end of McConnell Glaciation and it may have erupted as recently as the mid-Holocene (*see* 'Natural hazards' section).

APPLICATIONS

Engineering applications and geological hazards

Few detailed geotechnical investigations have been carried out within the study area with the exception of feasibility studies for dams on the Yukon and Pelly rivers. Consequently, characteristic values for such basic soil engineering parameters such as unconfined compressive strength and optimum Procter density for terrain units cannot be reported. However, some observations of the performance of these units in natural settings may prove valuable and are reported here.

Foundation conditions

Bedrock is characteristically competent in the study area. The one remarkable exception is the Carmacks Group which is highly prone to failure as complex landslides (*see* below).

With respect to Quaternary deposits, the distribution of permafrost and the presence of massive ice lenses are the pre-eminent factors to be considered in evaluating foundation conditions within the study area. Permafrost is defined as soil or rock that remains at or below 0°C for at least two years. Permafrost is widespread in the Carmacks map area. Its presence or absence is strongly influenced by microclimatic factors. For example, it is frequently patchy or absent on south-facing slopes and continuous on north-facing ones. The subsurface of permafrost terrain can be subdivided on thermal criteria into an active layer which thaws seasonally and an underlying perennially frozen layer. Active layer thickness is quite variable but 30–40 cm is common under peat soils in the map area (Burn, 1987). The perennially frozen layer is at least an order of magnitude thicker than this range. Permafrost may be dry, i.e. without the presence of extensive segregated ice bodies as is the case in areas of outcropping bedrock in the Dawson Range or in thick glaciofluvial gravels. Fine-grained inorganic or organic sediments invariably contain extensive bodies of segregated ice.

Colluvial deposits

Colluvial deposits are highly variable in texture and consequently are highly variable as foundation materials. Rockfall deposits (unit bCa) are coarse and porous but are often close to the angle of repose making them metastable. They may also locally creep and collapse due to interstitial ice content. Colluvial apron deposits (unit Ca) may be covered by blanket bog or contain buried organic layers which could pose differential consolidation problems. Those with matrices with sufficiently large silt fractions may contain segregated ice lenses. In addition to foundation concerns, both units Ca and bCa may lie in the path of periodic avalanching and debris flows. Colluvial blankets and veneers (units Cb, Cv), where they occur on sloping ground, are usually affected by solifluction and consequently creep during the warm months.

Alluvial deposits

Floodplains (units Ap, Au) are highly variable with respect to foundations conditions. Substrates range from thick gravel to ice-rich organic silt in oxbow lakes and backswamp areas to interstratifications of the two. Organic silt deposits are loci for thermokarst activity. Alluvial terraces and fans (units At, Af) are usually well drained and should be relatively free of massive ground ice. However alluvial fans are prone to inundation by water floods and debris flows.

Till

Till (units Mb, Mv) usually provides a stable strong substrate. Geomorphic processes affecting till blankets and veneers and till in hummocky ice disintegration topography are commonly confined to fluvial erosion. However, permafrost degradation has caused significant landsliding elsewhere in till in central Yukon Territory (Ward et al., 1992). Erosion is only of concern to the planner where erosion rates are rapid enough to cause gullying. Under natural conditions, such erosion usually is confined to river-cut cliffs.

Glaciofluvial and glaciolacustrine sediments

Natural hazards exist on glaciofluvial deposits only where they border other deposits such as avalanche or rockfall areas along valley margins. Glaciolacustrine deposits often contain massive ice lenses. Where they have been eroded, such as along the outside of river bends, the thawing fine sediments retreat rapidly as retrogressive thaw-slides. Where ice lenses are degrading at level sites, glaciolacustrine sediments are prone to vertical (thermokarst) collapse.

Organic sediments

The low bearing strength of organic sediment (unit O) coupled with their extensive contents of ice lenses makes them sensitive to disturbance and totally unsatisfactory as foundation substrates. Thawing of these sediments, once initiated, may spread dramatically beyond the original disturbance.

Eolian deposits

These sediments are usually thin (<1–2 m). Consequently, their suitability as a foundation material is dictated by units underlying them.

Granular materials

Bulk fill

Till (units Mb, Mv) is the most widespread glacial sediment in the study area. It is low in plasticity and if in situ moisture contents are low, it is easily exploited as a source for low permeability bulk fill. It has been widely used in fills and as a surface material in the Robert Campbell and Klondike highways, the major transportation arteries through the study area. However, where segregated ice lenses are present, moisture contents upon thawing are well in excess of the liquid limit and till will flow on gradients as low as 4°.

Glaciolacustrine sediments (L units) are locally extensive in major valleys and where they are free of ground ice, they are good sources of bulk fill. Where ground ice is present, in situ moisture content of these sediments will exceed the liquid limit upon thawing causing it to flow on very low gradients.

Sand and gravel

Sand and gravel are plentiful throughout the study area but accessibility and quality in terms of sorting (grading) and the content of undesirable or weak lithologies may range markedly. Any alluvial (A) or glaciofluvial (G) units are potential sources. Units Ap and Au are at or close to the water table and may be capped by organic and lacustrine sediments. Exploitation will disrupt streams and wetland environments. Post-McConnell and pre-McConnell At and Af units are typically well drained but unit Af deposits, particularly those underlying steep fans below small mountainous watersheds, are bouldery and contain poorly sorted debris-flow diamicton.

Glaciofluvial deposits are another major source of gravel. Glaciofluvial units are highly variable in texture and sorting over short distances both laterally and vertically and may contain variable amounts of diamicton.

Natural hazards

The processes that shape the Earth's surface are relentless. Where processes such as flooding and landsliding have the potential to threaten lives and property, they are labelled natural hazards. The following hazards are discussed in addition to the widespread permafrost-related problems described previously.

Earthquakes and volcanic activity

The study area is bordered to the west by two extremely active seismic belts, the North American Plate margin and the Denali Fault (Fig. 31). The former zone has produced some of the largest earthquakes recorded on the planet with magnitudes up to 8.6 (Stover et al., 1980; Horner, 1983). Large magnitude earthquakes from these sources have been felt in the Carmacks map area. The Mackenzie and Richardson mountains constitute another seismically active belt to the east and northeast from the Carmacks map area. This belt has produced earthquakes with magnitudes to 6.8 (Wetmiller et al., 1988). Only one damaging earthquake (1850) has been recorded in the map area during the past century and a half. The source of this earthquake remains a mystery although it was remote to the Carmacks area (Jackson, 1990). Volcanic activity occurred within the Carmacks map area at Volcano Mountain during the early Holocene or late Pleistocene (Fig. 32; Jackson and Stevens, 1992). Radiocarbon ages from the base of sediments accumulated in a lake ponded by a lava flow on the south side of Volcano Mountain indicate that the latest lava flows could have been erupted as recently as the mid-Holocene. The past patterns of eruption of Volcano Mountain suggest that any renewed volcanism would be local in scope and probably would not present a hazard beyond the immediate vicinity of the mountain. However, eruptions would likely be accompanied by local earthquake activity that would be felt over a larger area.

The most recently dated active faulting in the Carmacks area occurred during the eruption of Ne Ch'e Ddhäwa volcanic edifice beneath the ice sheet of the younger pre-Reid glaciation ca. 0.99–0.78 Ma BP (Jackson et al., 1996a, Fig. 4).

Floods and debris flows

Floods due to ice-jamming during spring break-up, snow melt, and summer rainstorms are potential hazards along streams throughout the study area. Areas designated units Ap and Au should be regarded as floodplain. Alluvial fans (unit Af) are also flood hazard areas. They are subject to both inundation with floodwaters and stream avulsion with the

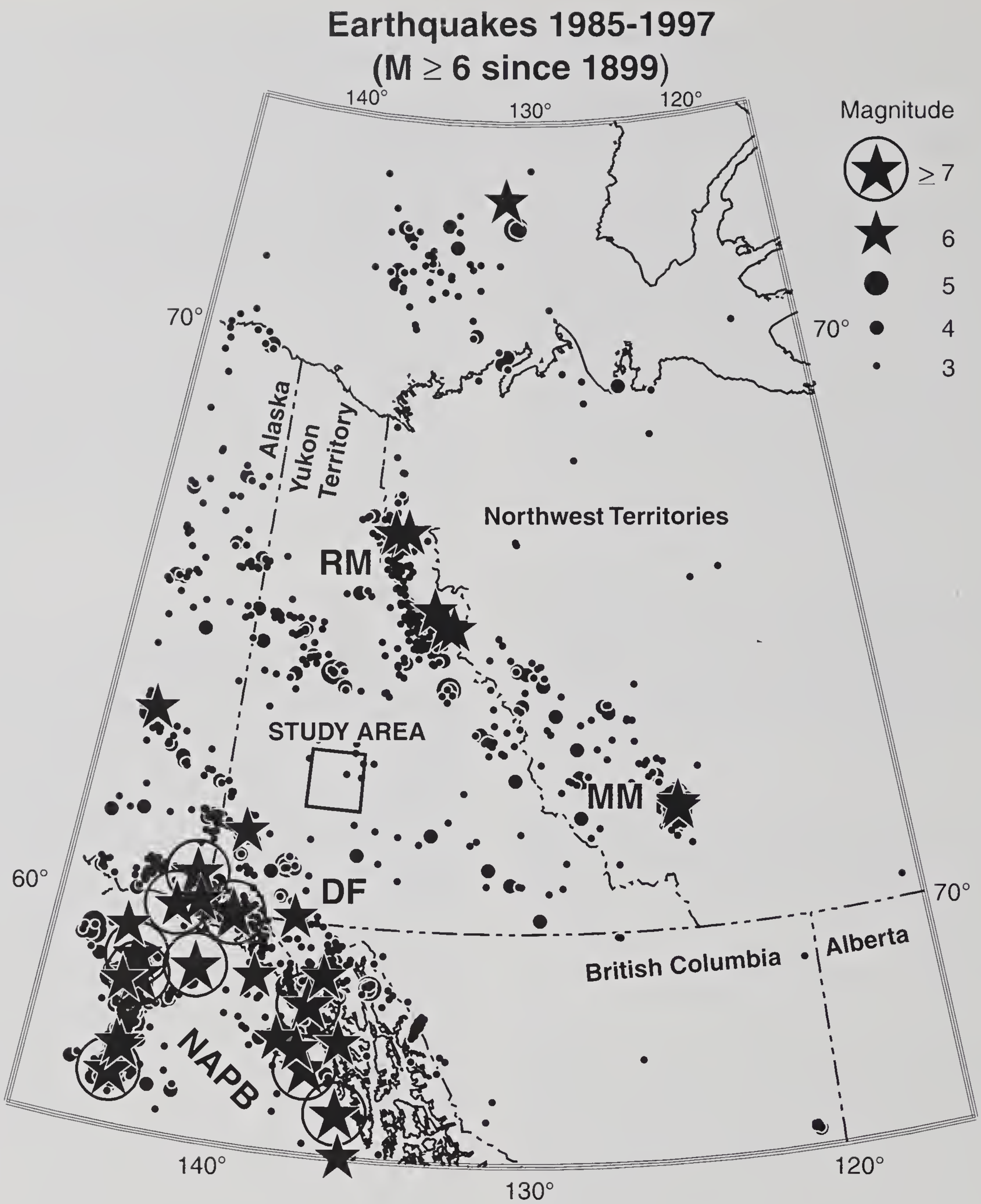


Figure 31. Seismic activity map, Yukon Territory and adjacent areas: RM-Richardson Mountains; MM-Mackenzie Mountains; NAPB-North American plate boundary; DF-Denali Fault.

added potential hazard of inundation by debris flows. Only alluvial terraces (At units), of all alluvial units, can be safely regarded as being beyond the reach of floodwaters. Colluvial aprons (unit Ca) may also be prone to inundation by debris flows and floodwaters with accompanying stream avulsion.

Landslides

Landslides large enough to be resolved at a scale of 1:100 000 are almost entirely confined to basaltic volcanic rocks of the Late Cretaceous Carmacks Group and the Selkirk volcanics. These formations are prone to failure because of their highly jointed structure and interstratification of fragmental and incompetent breccias and pyroclastic units with more competent ridge- and cliff-forming basalt flows. These fail as large rotational slumps and complex landslides. The largest landslide complex in the map area is postglacial and is located at the east end of Miller Ridge immediately northwest of Carmacks (Fig. 33). The complex is 7 km long and descends almost 400 m from crown to toe. Its planimetric width is up to 2.5 km. Another, apparently inactive landslide, which postdates Reid Glaciation, occurs on the north side of Miller's Ridge. It measures approximately 4 km by 5 km.

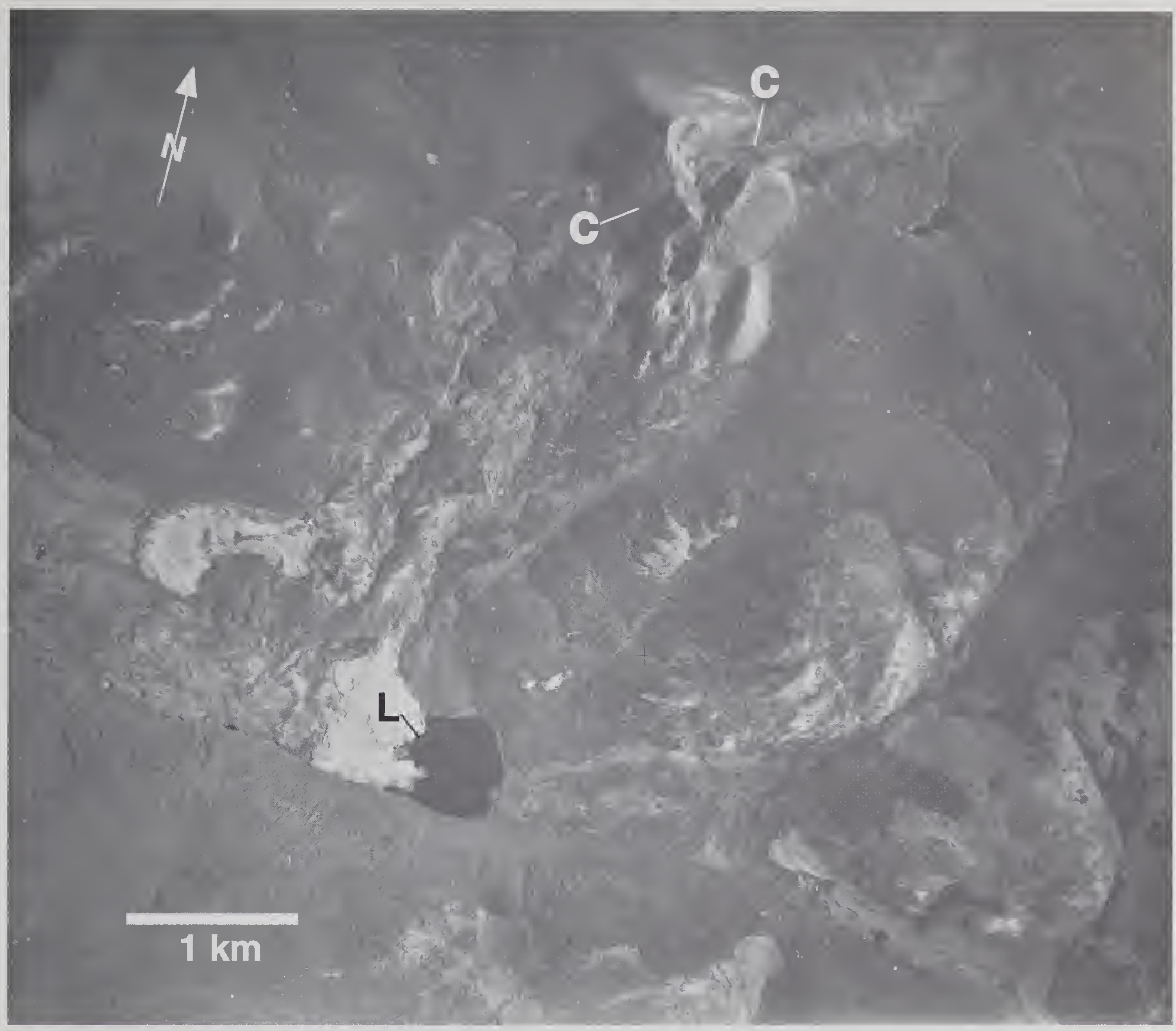


Figure 32. *Landslide and lava flows, Volcano Mountain. The cinder cone collapsed on the north and south flanks during the last eruption (C) due to undermining of outbreak eruptions of basalt from the flanks of the mountain. Radiocarbon dating of organic sediments retrieved from the lake dammed by the flows (L) have placed a mid-Holocene limit on the age of the last eruption (Jackson and Stevens, 1992). NAPL A12106-129*

Large landslides occurred on the northeast and southwest flanks of Volcano Mountain during its late Pleistocene or Holocene eruptions (Fig. 32; McConnell, 1903, Jackson and Stevens, 1992). The northeast crater rim collapsed and remnants were rafted along in a combination landslide and lava flow. Assuming that the unfailed cone had a regular surface, this failure involved approximately 1.5×10^7 m^3 of cone rim. Dimensions of individual blocks of the former crater rim range up to the size of small apartment buildings. The failure of the southwest side of the cone was triggered when lava flows broke out from its base undermining the overlying slope in the process. A conservative estimate of the volume of this failure, assuming a regular surface on the unfailed cone, is 7×10^6 m^3.

Elsewhere, smaller rotational slumps, measuring hundreds of metres parallel to the axis of rotation, are common in basalt flows of the Selkirk volcanics along Yukon River above Fort Selkirk.

Snow avalanches

Snow avalanching is a relatively rare phenomenon in the alpine areas of the Carmacks map area due to a lack of high mountains and the relative aridity of the area. It is a hazard only in and around a few of the highest peaks of the Dawson Range. Areas denoted R-A on maps are prone to avalanching and rockfall. Areas denoted Mv, Mb, Ca, bCa, and Af downslope of R-A areas should be regarded as potential avalanche or rockfall runout areas.

Placer gold exploration

Placer gold prospecting and mining has been carried out in Dawson Range, central Yukon Territory since 1898 (Bostock, 1936). Prospecting and mining activity has centred in the areas of Victoria Creek, Nansen Creek, and the Big Creek basin upstream from Stoddart Creek (Fig. 34). This area will henceforth be referred to as the Nansen–Big Creek placer district. The occurrence of placer gold in this region results from preglacial and middle Pleistocene weathering of gold-bearing Cretaceous granite and granodiorite units and their subvolcanic equivalent, the Mount Nansen Group and

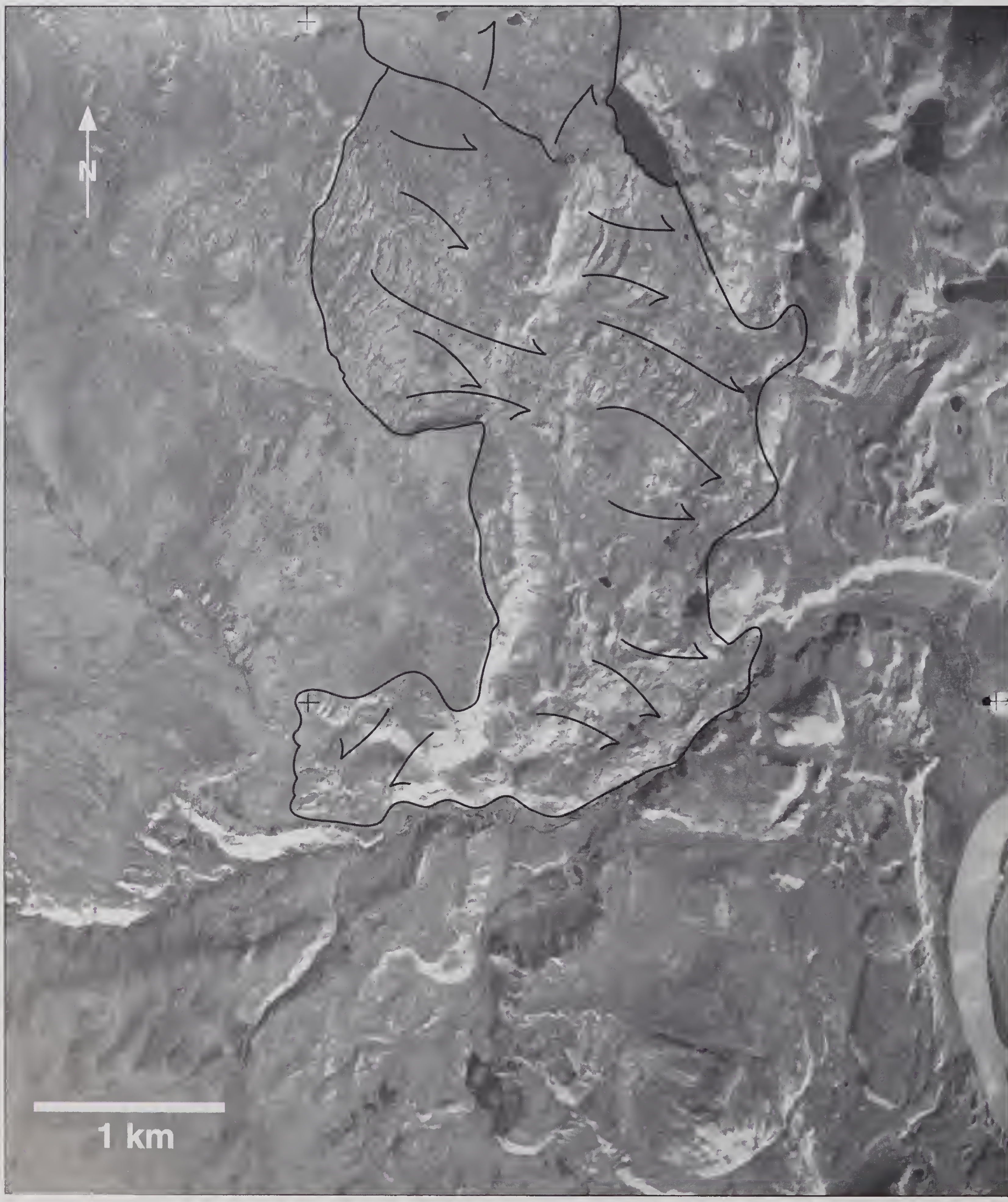


Figure 33. Landslide in Carmacks Group volcanic rocks, east end of Miller's Ridge. Drop from crown to toe is approximately 400 m. NAPL A11069-136

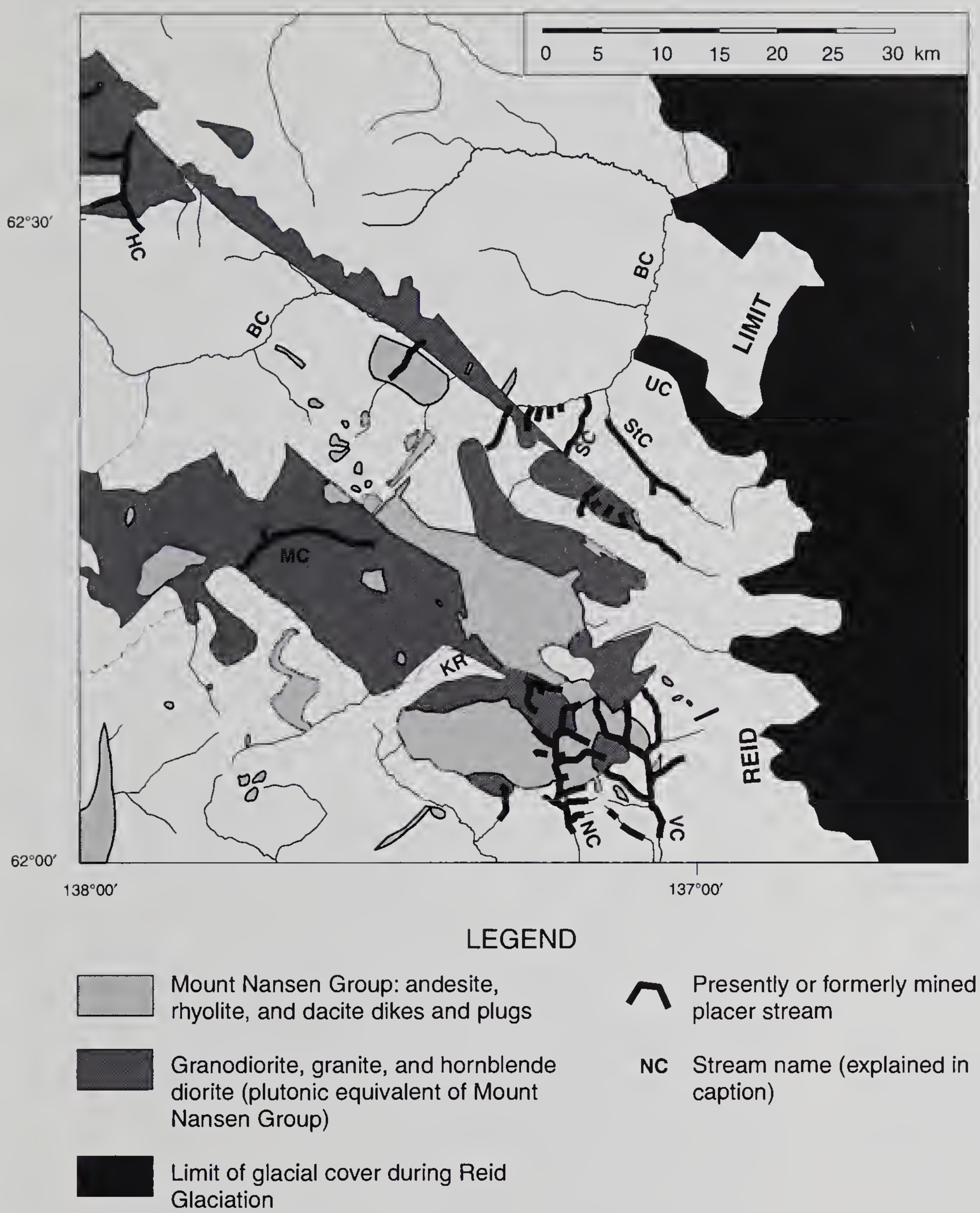


Figure 34.

Placer occurrences and generalized bedrock geology, Nansen–Big Creek placer district and adjacent Dawson Range. VC, Victoria Creek; NC, Nansen Creek; KR, Klaza River; MC, Mica Creek; HC, Hayes Creek; StC, Stoddart Creek; UC, Unnamed Creek; SC, Seymour Creek; BC, Big Creek.

no glacial erosion since the pre-Reid glaciations (Bostock, 1936; Jackson, 1993; LeBarge, 1995). All existing placer operations either overlie or are topographically downslope from these bedrock units (Fig. 34).

Placer deposits in the Nansen–Big Creek districts are usually found resting on deeply weathered bedrock e.g. Revenue Creek or on cohesive bouldery clay-rich pre-Reid glaciogenic diamicton (till) e.g. W.D.P. placer mine in upper Klaza River basin (Jackson, 1993). These placer deposits originated after the pre-Reid glaciations when streams in Dawson Range eroded their beds to bedrock or to clay-rich erosionally resistant till. This erosion through unknown but significant thicknesses of glacial sediments likely concentrated their gold contents; gold was contributed as well by direct erosion of bedrock or erosion of the colluvial mantle.

Placers along second- and third-order streams were subsequently buried by Reid Glaciation outwash and related aggradation where they were within areas disturbed by the glaciation. "Gulch" placer deposits on higher and steeper first-order streams were buried by angular, poorly sorted gravels (often with ventifacted clasts) delivered to the channel by creep of the colluvial mantle and progradation of small, steep alluvial fans. This aggradation cannot be linked to any specific glaciation or interglaciation at present. Placers along Back Creek on the west side of the Victoria Creek basin (Fig. 34) are capped by such coarse angular gravels.

LeBarge (1995) found that pre-Reid till itself can contain economic concentrations of gold. He concluded, on the basis of the morphology of gold found in till, that this enrichment was due to the incorporation of pre-existing alluvial placer deposits and overburden enriched in gold due to chemical weathering during preglacial or interglacial times.

Suggestions for future prospecting

Five recommendations may be made with respect to future placer prospecting in Dawson Range.

1. The factors that led to the deposition of known gold placer deposits in the Nansen–Big Creek placer district should also have been coincident elsewhere in the Dawson Range. Areas suggested for particular attention include drainage basins within or partly within the outcrop area of the Late Cretaceous granitic rocks and Mount Nansen Group (Fig. 4).

2. Placers that may exist on some of the larger streams such as Big Creek and Lonely Creek may be buried under a considerable depth of valley fill due to extensive aggradation during the Reid Glaciation. Smaller, steep, first-order tributaries in the upper parts of basins have the least overburden and are likely the most economically viable prospects.

3. Exploration should be concentrated beyond the limit of the Reid Glaciation, where glacial ice has not removed mid-Pleistocene placer deposits.

4. Existing geological maps and the outcrop pattern shown in Figure 4 should be only regarded as guides because outcrops are sparse and colluvial mantles are thick in Dawson Range. Clasts of granitic rocks or Mount Nansen Group lithologies present in stream gravels or in colluvium (exclusive of areas influenced by Reid outwash), indicate that these potential gold source rocks are present within the surrounding basin whether or not they have been mapped. These should be regarded as indicators of gold potential.

5. Pre-Reid outwash and till may constitute placer deposits. Pre-Reid glacial erosion incorporated a weathered and locally gold enriched bedrock mantle and placer gravels relict from Tertiary climates.

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REFERENCES

Atmospheric Environment Service

1982a: Canadian climate normals, temperature and precipitation 1951-1980, the north-Y.T. and N.W.T.; Environment Canada, Ottawa, Ontario, 55 p.

1982b: Canadian climate normals, temperature and precipitation 1951-1980, British Columbia; Environment Canada, Ottawa, Ontario, 268 p.

Barendregt, R.W. and Irving, E.

1998: Changes in the extent of North American ice sheets during the late Cenozoic; Canadian Journal of Earth Sciences, v. 35, p. 504–509.

Barendregt, R.W., Vincent, J.-S., Irving, E., and Baker, J.

1998: Magnetostratigraphy of Quaternary and late Tertiary sediments on Banks Island, Canadian Arctic Archipelago; Canadian Journal of Earth Sciences, v. 35, p. 147–161.

Berger, G.W., Pewe, T.L., Westgate, J.A., and Preece, S.J.

1996: Age of the Sheep Creek Tephra (Pleistocene) in central Alaska from thermoluminescence dating of bracketing loess; Quaternary Research, v. 45, p. 263–270.

Bostock, H.S.

1936: Carmacks district, Yukon; Geological Survey of Canada, Memoir 189, 58 p.

1966: Notes on glaciation in central Yukon Territory; Geological Survey of Canada, Paper 65–56, 18 p.

Boulton, G.S.

1970: On deposition of meltout tills at the margins of certain Svalbard glaciers; Journal of Glaciology, v. 9, p. 231–246.

Boulton, G.S. and Eyles, N.

1979: Sedimenation by valley glaciers: a model and genetic classification; *in* Moraines and Varves, (ed.) C. Schluchter; Balkema Press, Rotterdam, Netherlands, p. 11–24.

Boyle, R.W.

1979: The geochemistry of gold and its deposits; Geological Survey of Canada, Bulletin 280, 584 p.

Brown, R.J.E.

1978: Permafrost; Plate 32 *in* Hydrological Atlas of Canada; Fisheries and Environment Canada, Ottawa, 32 Pl.

Burn, C.R.

1987: Permafrost; *in* XIIth International Quaternary Association (INQUA) Congress Field Excursions A20a and A20b, (ed.) S.R. Morison and C.A.S. Smith; National Research Council, Ottawa, Ontario, p. 21–25.

1992: Recent ground warming inferred from the temperature in permafrost near Mayo, Yukon Territory; Periglacial Geomorphology, (ed.) J.C. Dixon and A.D. Abrahams; John Wiley and Sons Ltd., Toronto, Ontario, p. 327–350.

Burn, C.R., Michel, F.A., and Smith, M.W.

1986: Stratigraphic, isotopic and mineralogical evidence for an early Holocene thaw unconformity at Mayo, Yukon Territory; Canadian Journal of Earth Sciences, v. 23, p. 794–803.

Cairns, D.D.

1910: Lewes and Nordenskiold rivers coal district; Geological Survey of Canada, Memoir 5, 70 p.

1912: Geology of a portion of the Yukon-Alaska boundary between Porcupine and Yukon rivers; Geological Survey of Canada, Summary Report 1912.

1915: Exploration in southwestern Yukon; *in* Summary Report of the Geological Survey, Department of Mines, 1914, Geological Survey of Canada, Sessional Paper No. 26, p. 10–28.

Canada Soil Survey Committee

1978: Canadian System of Soil Classification; Agriculture Canada, Ottawa, Publication 1646, 164 p.

Cande, S.C. and Kent, D.V.

1995: Revised calibration of the geomagnetic polarity timescale for the Late Cretaceous and Cenozoic; Journal of Geophysical Research, v. 100, no. B4, p. 6093–6095.

Church, M. and Ryder, J.M.

1972: Paraglacial sedimentation: a consideration of fluvial processes conditioned by glaciation; Geological Society of America Bulletin, v. 83, p. 3059–3072.

Clague, J.J.

1982: Minimum age of deglaciation of upper Elk Valley, British Columbia: discussion; Canadian Journal of Earth Sciences, v. 19, p. 1099–1100.

Clark, D.L., Chern, L.A., Hogler, J.A., Mennicke, C.M., and Atkins, E.D.

1990: Late Neogene climate evolution of the central Arctic Ocean; *in* Arctic Geoscience, (ed.) J.R. Weber, D.A. Forsyth, A.F. Embry, and S.M. Blasco; Marine Geology, v. 93, p. 69–94.

Dawson, G.M.

1887: Report on the exploration in the Yukon District, N.W.T. and adjacent northern portion of British Columbia; Geological Survey of Canada, Annual Report 1887-88, Part B.

Dreimanis, A.

1982: INQUA-Commission on genesis and lithology of Quaternary deposits. Work group (1) - genetic classification of tills and criteria for their differentiation: progress report on activities 1977-1982, and definitions of glacigenic terms; *in* INQUA Commission on Genesis and Lithology of Quaternary Deposits, (ed.) C. Schlüchter; Report on Activities 1977-1982, Zurich, p. 12–31.

1988: Tills: their genetic terminology and classification; *in* Genetic Classification of Glacigenic Deposits, (ed.) R.P. Goldthwait and C.L. Matsch; A.A. Balkema, Rotterdam, 294 p.

Drumke, J.S.

1964: A systematic survey of Corylus in North America; PhD. thesis, University of Tennessee, Knoxville, Tennessee, 142 p.

Dubois, P.M.
1959: Late Tertiary geomagnetic field in northwestern Canada; Nature, v. 183, p. 1617–1618.
Duk-Rodkin, A. and Barendregt, R.W.
1997: Glaciations of Gauss and Matuyama age in the Tintina Trench, Dawson area, Yukon Territory; *in* Abstracts 1997 Biennial Meeting of the Canadian Quaternary Association, (CANQUA), p. 22.
Duk-Rodkin, A., Barendregt, R.W., Tarnocai, C., and Phillips, F.M.
1996: Late Tertiary to late Quaternary record in the Mackenzie Mountains, Northwest Territories, Canada: stratigraphy, paleosols, paleomagnetism, and chlorine-36; Canadian Journal of Earth Sciences, v. 33, p. 875–895.
Eyles, N., Eyles, C.H., and Miall, A.D.
1983: Lithofacies types and vertical profile models; an alternative approach to the description and environmental interpretation of glacial diamict and diamictive sequences; Sedimentology, v. 30, p. 393–410.
Foscolos, A.E., Rutter, N.W., and Hughes, O.L.
1977: The use of pedological studies in integrating the Quaternary history of central Yukon; Geological Survey of Canada, Bulletin 271, 48 p.
Francis, D. and Ludden, J.
1990: The mantle source for olivine nephelinite, basanite and alkaline olivine basalt at Fort Selkirk, Yukon, Canada; Journal of Petrology, v. 31, p. 371–400.
Froese, D.G., Barendregt, R.W., Duk-Rodkin, A., Enkin, R.J., Baker, J., and Smith, D.G.
1997: Sedimentology and paleomagnetism of Pliocene-Pleistocene lower Klondike valley terrace sediments, west-central Yukon; *in* Abstracts, 1997 Biennial Meeting of the Canadian Quaternary Association, p. 24.
Fuller, E.A.
1986: Yukon river evolution since White River ash; M.Sc. thesis, Simon Fraser University, Burnaby, British Columbia, 168 p.
Fuller, E.A. and Hughes, O.L.
1987: Sand wedges in pre-Reid sand and gravel; *in* XIIth International Quaternary Association (INQUA) Congress Field Excursions A20a and A20b, (ed.) S.R. Morison and C.A.S. Smith; National Research Council, Ottawa, Ontario, p. 56–58.
Gardner, J.S.
1979: Movement of material on debris slopes in the Canadian Rocky Mountains; Zeitschrift für Geomorphologie N.F., v. 27, p. 311–324.
1980: Frequency and magnitude and spatial distribution of mountain rockfalls and rockslides in the Highwood Pass area, Alberta, Canada; *in* Thresholds in Geomorphology, (ed.) D.R. Coates and J.D. Vitek; Allen and Unwin, Toronto, Ontario, p. 267–295.
1983: Rockfall frequency and distribution in the Highwood Pass area, Canadian Rocky Mountains; Zeitschrift für Geomorphologie N.F., vol. 27, p. 311–324.
Geurts, M.-A. and Dewez, V.
1993: Le lac glaciare Nisling et le pléistocène dans le bassin supérieur de la Nisling River, au Yukon; Gèographie physique et Quarternaire, vol. 47, p. 81–92.
Grond, H.C., Churchill, S.J., Armstrong, R.L., Harakal, J.E., and Nixon, G.T.
1984: Late Cretaceous age of the Hutshi, Mt. Nansen, and Carmacks groups, southwestern Yukon; Canadian Journal of Earth Sciences, v. 21, p. 554–558.
Hallberg, G.R.
1986: Pre-Wisconsin glacial stratigraphy of the central plains region in Iowa, Nebraska, Kansas and Missouri; *in* Quaternary Glaciations in the Northern Hemisphere, (ed.) V. Sibrava, D.Q. Bowen, and G.M. Richmond; Quaternary Science Reviews, v. 5, p. 11–15.
Hamilton, T.D.
1991: Late Cenozoic glaciation of Alaska; *in* The Geology of Alaska, (ed.) G. Plafker and H.C. Berg; The Geology of North America, v. G-1, Geological Society of America, Boulder, Colorado, p. 813–844.
Hayes, C.W.
1892: Exploration through the Yukon District; National Geographic Magazine, v. IV, p. 118–162.
Herman, Y.
1970: Arctic paleo-oceanography in late Cenozoic time; Science v. 169, p. 474–477.
Herman, Y., Grazzini, C.V., and Hooper, C.
1971: Arctic paleotemperatures in late Cenozoic time; Nature, v. 232, p. 466–469.
Horner, R.B.
1983: Seismicity in the St. Elias region of northwestern Canada and southeastern Alaska; Seismological Society of America Bulletin, v. 3, p. 1117–1137.
Howes, D.E. and Kenk, E.
1988: Terrain classification system for British Columbia (revised edition); Ministry of Environment and Ministry of Crown Lands, Victoria, British Columbia, MOE Manual 10, 90 p.
Hughes, O.L.
1969: Distribution of open system pingoes in central Yukon with respect to glacial limits; Geological Survey of Canada, Paper 69-34, 8 p.
1989: Quaternary chronology, Yukon and western district of Mackenzie; *in* Late Cenozoic History of the Interior Basins of Alaska and the Yukon; (ed.) L.D. Carter, T.D. Hamilton, and J.P. Galloway; United States Geological Survey, Circular 1026, p. 25–29.
1990: Surficial geology and geomorphology, Aishihik Lake, Yukon Territory; Geological Survey of Canada, Paper 87-29, 23 p.
Hughes, O.L., Campbell, R.B., Muller, J.E., and Wheeler, J.O.
1969: Glacial limits and flow patterns, Yukon Territory, south of 65 degrees north latitude; Geological Survey of Canada, Paper 68-34, 9 p.
Hughes, O.L., Rutter, N.W., and Clague, J.J.
1989: Yukon Territory (Quaternary stratigraphy and history, Cordilleran Ice Sheet); *in* Chapter 1 of Quaternary Geology of Canada and Greenland, (ed.) R.J. Fulton; Geological Survey of Canada, Geology of Canada, no. 1 (*also* Geological Society of America, The Geology of North America, v. K-1), p. 58–62.
Jackson, L.E., Jr.
1987: Debris flow hazard in the Canadian Rocky Mountains; Geological Survey of Canada, Paper 86-11, 20 p.
1989: Pleistocene subglacial volcanism near Fort Selkirk, Yukon Territory; *in* Current Research, Part E; Geological Survey of Canada, Paper 89-1E, p. 251–256.
1990: Oldest dated earthquake in Yukon Territory, Canada; Canadian Journal of Earth Sciences, v. 27, p. 818–819.
1993: Origin and stratigraphy of Pleistocene gravels in Dawson Range and suggestions for future exploration of gold placers, southwestern Carmacks map area (115-I); *in* Current Research, Part A; Geological Survey of Canada, Paper 93-1A, p. 1–10.
Jackson, L.E., Jr. and Harington, C.R.
1991: Pleistocene mammals, stratigraphy and sedimentology at the Ketza River site, Yukon Territory; Géographic physique et Quarternaire, v. 44, p. 69–77.
Jackson, L.E., Jr. and MacKay, T.D.
1990: Glacial limits and ice-flow directions of the last Cordilleran Ice Sheet in Yukon Territory between 60 and 63 degrees north; Geological Survey of Canada, Open File 2329 (digital file).
Jackson, L.E., Jr. and Stevens, W.
1992: A recent eruptive history of Volcano Mountain, Yukon Territory; *in* Current Research, Part A; Geological Survey of Canada, Paper 92-1A, p. 33–39.
Jackson, L.E., Jr., Barendregt, R., Baker, J., and Irving, E.
1996a: Early Pleistocene volcanism and glaciation in central Yukon: new chronology from field studies and paleomagnetism; Canadian Journal of Earth Sciences, v. 33, p. 904–916.
Jackson, L.E., Jr., Barendregt, R., Irving, E., and Ward, B.
1990: Magnetostratigraphy of early to middle Pleistocene basalts and sediments, Fort Selkirk area, Yukon Territory; *in* Current Research, Part E; Geological Survey of Canada, Paper 90-1E, p. 277–286.

Jackson, L.E., Jr., Kostaschuk, R.A., and MacDonald, G.M.
1987: Identification of debris flow hazard on alluvial fans in the Canadian Rocky Mountains; *in* Debris Flows/avalanches: Process, Recognition, and Mitigation; (ed.) J.E. Costa and G.F. Wieczorek; Geological Society of America, Reviews in Engineering Geology, Volume VII, p. 115–124.

Jackson, L.E., Jr., MacDonald, G.M., and Wilson, M.C.
1982: Paraglacial origin for terraced river sediments in Bow Valley, Alberta; Canadian Journal of Earth Sciences, v. 19, p. 2219–2213.

Jackson, L.E., Jr., Tarnocai, C., and Mott, R.J.
in press: A middle Pleistocene paleosol sequence from Dawson Range, central Yukon Territory; Géographie physique et Quaternaire.

Jackson, L.E., Jr., Telka, A., and Jetté, H.
1996b: A pre-Wisconsinan glacial/interglacial record, Revenue Creek, central Yukon; *in* Program and Abstracts, 14th Biennial Meeting of the American Quaternary Association, Flagstaff, Arizona, p. 91.

Jackson, L.E., Jr., Ward, B.C., Duk-Rodkin, A., and Hughes, O.L.
1991: The last Cordilleran ice sheet in Yukon Territory; Géographie physique et Quaternaire, v. 45, p. 341–354.

Jonasson, I.R., Jackson, L.E., Jr., and Sangster, D.F.
1983: A Holocene zinc orebody formed by the supergene replacement of mosses; Journal of Geochemical Exploration, v. 18, p. 189–194.

Klassen, R.W.
1987: The Tertiary-Pleistocene stratigraphy of the Liard Plain, southeastern Yukon Territory; Geological Survey of Canada, Paper 86-17, 16 p.

Klassen, R.W. and Morison, S.R.
1987: Surficial geology, Carmacks, Yukon Territory; Geological Survey of Canada, Map 9-1985, scale 1:250 000.

Lawson, D.E.
1981: Sedimentological characteristics and classification of depositional processes and deposits in the glacial environment; U.S. Army Cold Regions Research and Engineering Laboratory, Report 81-27, 16 p.
1988: Glacigenic resedimentation: classification, concepts, and application to mass-movement processes and deposits; *in* Genetic Classification of Glacigenic Deposits, (ed.) R.P. Goldthwait and C.L. Matsch; Balkema, Rotterdam, 294 p.

LeBarge, W.P.
1995: Sedimentology of placer gravels near Mt. Nansen, central Yukon Territory; Exploration and Geological Services Division, Indian and Northern Affairs Canada, Yukon Region, Bulletin 4, 155 p.

Levson, V.M. and Rutter, N.W.
1988: A lithofacies analysis and interpretation of depositional environments of montane glacial diamictons, Jasper Alberta, Canada; *in* Genetic Classification of Glacigenic Deposits, (ed.) R.P. Goldthwait and C.L. Matsch; A.A. Balkema, Rotterdam, p. 117–140.

Lundqvist, J.
1980: Glacigenic processes, deposits and landforms; *in* Genetic Classification of Glacigenic Deposits, (ed.) R.P. Goldthwait and C.L. Matsch; A.A. Balkema, Rotterdam, p. 3–16.

MacDonald, G.M.
1983: Holocene vegetational history of the upper Natla River area, Northwest Territories, Canada; Arctic and Alpine Research, v. 15, p. 169–180.

Mankinen, E.A. and Dalrymple, G.B.
1979: Revised geomagnetic polarity time scale for the interval 0-5 m.y.b.p.; Journal of Geophysical Research, v. 84, no. B2, p. 615–626.

Mathews, W.H.
1986: Physiographic map of the Canadian Cordillera; Geological Survey of Canada, Map 1701, scale 1:5 000 000.

Matthews, J.V., Schweger, C.E., and Hughes, O.L.
1990: Plant and insect fossils from the Mayo Indian Village section (central Yukon): new data on middle Wisconsinan environments and glaciation; Géographie physique et Quateraire, v. 44, p. 15–26.

McConnell, R.G.
1888: Report on an exploration in the Yukon and Mackenzie basins, N.W.T.; Geological Survey of Canada, Annual Report 1888-89, v. IV, part D, p. 1–25.

McConnell, R.G. (cont.)
1903: The Macmillan River; Geological Survey of Canada, Summary Report for 1902, v. XV, pt. A, p. 15–26.
1908: Klondike District (Report on gold values in the Klondike high level gravels, Pub. 979); Geological Survey of Canada, Summary Report for 1906, p. 17, 20–30.

Naeser, N.D., Westgate, J.A., Hughes, O.L., and Péwé, T.L.
1982: Fisson-track ages of late Cenozoic distal tephra beds in the Yukon Territory and Alaska; Canadian Journal of Earth Sciences, v. 19, p. 2167–2178.

Owen, E.B.
1959a: Fort Selkirk dam site; Geological Survey of Canada, Topical Report No. 15, 12 p.
1959b: Fort Selkirk saddle dam site; Geological Survey of Canada, Topical Report No. 16, 9 p.

Péwé, T.L.
1959: An observation of wind-blown loess; Journal of Geology, v. 59, p. 399–401.
1975: Quaternary geology of Alaska; United States Geological Survey, Professional Paper 835, 145 p.

Rampion, V.N.
1971: Late Pleistocene glaciations of the Snag-Klutlin area, Yukon Territory, Canada; Arctic, v. 24, p. 277–300.

Russell, I.C.
1890: Notes on the surface geology of Alaska (with discussion by N.S. Shaler and T.C. Chamberlain); Geological Society of America Bulletin, v. 1, p. 99–162.

Ryder, J.M.
1971a: The stratigraphy and morphology of paraglacial fans in south-central British Columbia; Canadian Journal of Earth Sciences, v. 8, p. 279–298.
1971b: Some aspects of morphology of paraglacial fans in south-central British Columbia; Canadian Journal of Earth Sciences, v. 8, p. 1252–1264.

Schweger, C.E. and Matthews, J.V., Jr.
1991: The last (Koy-Yukon) interglaciation in the Yukon: comparisons with Holocene and interstadial pollen records; Quaternary International, v. 10, p. 85–94.

Shackleton, N.J. and Opdyke, N.D.
1973: Oxygen isotope and paleomagnetic stratigraphy of equitorial Pacific core V28-238: oxygen isotope temperatures and ice volumes on a 10^5 and 10^6 year scale; Quaternary Research, v. 3, p. 39–55.

Shackleton, N.J., Berges, A., and Peltier, W.R.
1990: An alternate astronomical calibration of the lower Pleistocene time-scale based on ODP site 677; Transactions of the Royal Society of Edinburgh: Earth Sciences, v. 81, p. 251–261.

Shaw, J.
1979: Genesis of Sveg tills and Rogen moraines in central Sweden: a model for basal meltout; Boreas, v. 8, p. 409–426.
1985: Subglacial and ice marginal environments; *in* Glacial Sedimentary Environments, (ed.) G.M. Ashley, J. Shaw, and N.D. Smith; Society of Paleontologists and Mineralogists, Short Course No. 16, p. 7–84.

Sinclair, P.D., Temperman-Kluit, D.J., and Medaris, L.G., Jr.
1978: Llerzolite nodules from a Pleistocene cinder cone in central Yukon; Canadian Journal of Earth Sciences, v. 15, p. 220–226.

Smith, C.A.S., Tarnocai, C., and Hughes, O.L.
1986: Pedological investigations of Pleistocene glacial drift surfaces in the central Yukon; Geographie physique et Quarternaire, v. 40, p. 29–37.

Smith, N.D. and Ashley, G.M.
1985: Proglacial lacustrine environment; *in* Glacial Sedimentary Environments, (ed.) G.M. Ashley, J. Shaw, and N.D. Smith; Society of Economic Paleontologists and Mineralogists, Short Course No. 16, p. 135–216.

Soil Classification Working Group
1998: The Canadian System of Soil Classification (3rd ed.); Agriculture and Agri-Food Canada, Ottawa, Publication 1646, 187 p.

Stover, C.W., Reagor, B.G., and Wetmiller, R.J.
1980: Intensities and isoseismal map for the St. Elias earthquake of February 28, 1979; Seismological Society of America Bulletin, v. 70, p. 1635–1649.

Tarnocai, C.
1987: Quaternary soils; *in* Research in Yukon, (ed.) S.R. Morison and C.A.S. Smith; XIIth International Quaternary Association (INQUA) Congress Field Excursions A20a and A20b, National Research Council, Ottawa, Ontario, p. 16–21.
1989: Paleosols of northwestern Canada; *in* Late Cenozoic History of the Interior Basins of Alaska and Yukon, (ed.) L.D. Carter, T.D. Hamilton, and J.P. Galloway; United States Geological Survey, Circular 1026, p. 39–44.

Tarnocai, C. and Schweger, C.E.
1991: Late Tertiary and early Pleistocene paleosols in northwestern Canada; Arctic, v. 44, p. 1–11.

Tarnocai, C. and Valentine, K.W.G.
1989: Relict soil properties in Arctic and sub-Arctic regions of Canada; *in* Paleopedology: Nature and Application of Paleosols, (ed.) A. Bronger and J.A. Catt, J.A.; Catena supplement 16, p. 9–39.

Tarnocai, C., Smith, S., and Hughes, O.L.
1985: Soil development on Quaternary deposits of various ages in central Yukon; *in* Current Research, Part A; Geological Survey of Canada, Paper 85-1A, p. 229–238.

Tempelman-Kluit, D.K.
1978: Reconnaissance geology, Laberge map-area, Yukon; Geological Survey of Canada, Paper 78-1, p. 61–66.
1980: Evolution of physiography and drainage in southern Yukon; Canadian Journal of Earth Science, v. 17, p. 1189–1203.
1984: Geology, Laberge (105E) and Carmacks (115I), Yukon Territory; Geological Survey of Canada, Open File 1101, scale 1:250 000.

Theide, J., Clark, D.L., and Herman, Y.
1990: Late Mesozoic and Cenozoic paleoceanography of the northern polar oceans; *in* The Arctic Ocean Region, (ed.) A. Grantz, L. Johnson, and J.F. Sweeny; The Geology of North America, v. L, Geological Society of America, Boulder, Colorado, p. 427–458.

Tyrrell, J.B.
1901: Dalton trail, from Haines, Alaska to Carmacks, and explorations of the Nisling River; Geological Survey of Canada, Summary Report for 1898 (1899) and Annual Report, v. XI, 1898, pt. A, p. 24, 36–62.

Vernon, P. and Hughes, O.L.
1966: Surficial geology Dawson, Larsen Creek, and Nash map areas; Geological Survey of Canada, Bulletin 136, 25 p.

Wahl, H.E. and Goos, T.O.
1987: Climate; *in* XIIth International Quaternary Association (INQUA) Congress Field Excursions A20a and A20b, (ed.) S.R. Morison and C.A.S. Smith; National Research Council, Ottawa, Ontario, p. 7–12.

Wahl, H.E., Fraser, D.B., Harvey, R.C., and Maxwell, J.B.
1987: Climate of Yukon; Environment Canada, Atmospheric Environment Service, Climatological Studies no. 40, 319 p.

Ward, B.C.
1989: Quaternary stratigraphy along Pelly River in Glenlyon and Carmacks map areas, Yukon Territory; *in* Current Research, Part E; Geological Survey of Canada, Paper 89-1E, p. 257–264.
1993: Quaternary geology of the Glenlyon map area (105L), Yukon Territory; Ph.D. thesis, University of Alberta, Edmonton, Alberta, 209 p.

Ward, B.C., Jackson, L.E. Jr., and Savigny, K.W.
1992: Evolution of Surprise Rapids landslides, Yukon Territory; Geological Survey of Canada, Paper 90-18, 25 p.

Westgate, J.A.
1989: Isothermal plateau fission-track ages of hydrated glass shards from silicic tephra beds; Earth and Planetary Science Letters, v. 95, p. 226–234.

Wetmiller, R.J., Horner, R.B., Hasegawa, H.S., North, R.G., Lamontagne, M., Weichert, D.H., and Evans, S.G.
1988: An analysis of the 1985 Nahanni earthquakes; Seismological Society of American Bulletin, v. 78, p. 590–616.

Wright, A.A.
1976: Prelude to Bonanza; Grays Publishing Ltd., Sidney, British Columbia, 321 p.

ERRATA

The paleosol depicted in section 2, Map 1878A should be correctly labeled "buried soil" and the symbol denoting the paleosol in the legend for that section should read "buried soil developed after the McConnell Glaciation".

The unit described as "lapilli" in sections 2 and 2A, Map 1877A has been found to be pebble gravel partly melted and fused by the heat of the overlying lava flows.

APPENDICES A–E

A – Analysis of the Pony Creek core

B – Palynological Report No. 89-15

C – Palynology of Revenue Creek main (downstream) and upstream sections. Report PR-95.01

D – Macrofossil identifications

E – Wood identifications from Revenue Creek

APPENDIX A

ANALYSIS OF THE THE PONY CREEK CORE (DDH-115)

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(Edited by L.E. Jackson, Jr.)

INTRODUCTION

Core DDH-115 was drilled by Archer-Cathro and Associates (1981) Ltd. at an elevation of 1500 m on their Mount Nansen on a divide above Pony Creek, Dawson Range (Map 1876A, section 3). The core was drilled at an angle of 45° to the vertical through the fill in an ice margin channel last active during the youngest pre-Reid glaciation. Four paleosols were observed in this core comprised of a sequence of three paleosols (paleosols 1 to 3) between 16.33 m and 20.81 m depth, and a single paleosol (paleosol 4) between 27.70 m and 29.90 m.

Numerous paleosol studies have been carried out on pre-Reid (pre-Illinoian) paleosols in Yukon Territory and in the Mackenzie Mountains of the western Northwest Territories (Foscolos et al., 1977; Tarnocai et al., 1985; Smith et al., 1986; Tarnocai, 1987; Tarnocai and Smith, 1989; Hughes et al., 1993; Duk-Rodkin et al., 1996). Although the Mackenzie Mountain paleosols (Hughes et al., 1993; Duk-Rodkin et al., 1996) were buried, most of the Yukon Territory paleosols studied occurred on the surface. They were thus affected not only by the soil-forming processes that occurred after the youngest pre-Reid glaciation and before the Reid Glaciation, but also by the strong cryogenic processes that occurred after pedogenesis during the subsequent Reid and McConnell glaciations. The significance of the Mount Nansen paleosols is that they were buried quickly enough after formation that they were unaffected by subsequent soil-forming periods and disturbance by periglacial processes. Thus their properties probably reflect the soil formation and environments during a single interglacial period.

Table A-1. Morphological characteristics of the Mount Nansen Podzolic paleosols.

Horizon	Depth[a] (cm)	Vertical depth[b] (m)	Vertical horizon thickness (cm)	Colour	Texture[c]
Paleosol 1					
Ah	0–30	11.55–11.76	21	10YR 7/3	SL
Bf1	30–50	11.76–11.90	14	7.5YR 5/6	SL
Bf2	50–67	11.90–12.02	12	10YR 6/6	SL
Paleosol 2					
2Ah	67–162	12.02–12.69	67	10YR 5/2	SL
2Bf1	162–215	12.69–13.06	37	75YR 5/6	SL
2Bf2	215–237	13.06–13.22	16	10YR 6/6	SL
Paleosol 3					
3A	237–255	13.22–13.35	13	10YR 6/2	SL
3AB	255–270	13.35–13.46	11	10YR 6/6	SL
3Bf1	270–274	13.46–13.49	3	7.5YR 6/6	Si
3Bf2	274–448	13.49–14.82	133	7.5YR 4/4	SL
3C	448+	14.82+	NA	10YR 7/2	NA
Paleosol 4					
Bm1	0–107	19.59–20.35	76	7.5YR 7/2	SL
Bf1	107–180	20.34–20.87	52	7.5YR 7/8	SL
Bf2	180–192	20.86–20.96	9	7.5YR 5/6	SL
Bf3	192–220	20.95–21.16	20	ND	SL
R	220+	21.26+	NA	ND	S

[a] Depths are measured on the core, which was taken at an angle of 45° to the vertical
[b] Calculated depths of horizons from the surface (vertical)
[c] S, sandy; SL, sandy loam; Si, silty
NA, not applicable
ND, no data

METHODS

The paleosols and other sediments within the core were described and sampled at the drill site. The description and sampling of the paleosols were carried out using methods outlined in the *Manual for Describing Soils in the Field* (Agriculture Canada Expert Committee on Soil Survey, 1987). All soil descriptions were recorded on CanSIS detailed forms.

Analytical methods used are outlined in Sheldrick (1984). The methods used are: pH in 0.01 M $CaCl_2$; C and N by a Leco-600 determinator; extractable Fe and Al by the ammonium oxalate and sodium pyrophosphate methods; particle size distribution by pipette analysis; and $CaCO_3$ equivalents (in per cent) by the gravimetric method. Mineralogical analysis was carried out by X-ray diffraction using the less than 2 μm soil fraction.

DESCRIPTION AND DEVELOPMENT OF PALEOSOLS

These four paleosols developed under well drained conditions on colluvial materials that were periodically deposited, burying the paleosol. All of the paleosols have similar podzolic soil development with a well developed Bf horizon (>1% ammonium oxalate extractable Fe+Al), indicating that considerable time passed between the various burials. The morphological characteristics and analytical data are presented in Tables A-1 through A-5.

Paleosol 1

This paleosol is noncalcareous and has a slightly acid reaction (pH 6.1–6.4). The Ah horizon has a sandy loam texture with relatively high organic carbon content (1.07%). Even though this soil horizon has a relatively high organic carbon content, it is light in colour (10YR 7/3). The two underlying Bf horizons also have sandy loam textures and are slightly cemented, although the Bf2 horizon is much harder than the Bf1. This paleosol is the shallowest of all paleosols described in this core and contains a smaller amount of kaolinite in the B horizon than do the underlying paleosols.

Paleosol 2

This paleosol is very similar to paleosol 1, except it has a much deeper solum. It is noncalcareous to slightly calcareous with a slightly acid reaction (pH 6.1–6.4). The Ah horizon has a sandy loam texture and a slightly high organic carbon content (0.81%). The calcium carbonate content (2.05%) is probably due to carbonates leached out of paleosol 1. The two underlying Bf horizons also have sandy loam textures. The B horizon of this paleosol contains moderate amounts of kaolinite.

Paleosol 3

This paleosol is more highly developed than paleosols 1 and 2, and has the deepest solum (160 cm). It has moderate amounts of kaolinite and some minor amounts of interstratified minerals. It is noncalcareous to slightly calcareous with a

Table A-2. Selected chemical and physical data for the Mount Nansen Podzolic paleosols.

Horizon	$CaCO_3$ (%)	pH	C (%)	Total sand (%)	Silt (%)	Clay (%)
			Paleosol 1			
Ah	1.13	6.1	1.07	56.4	36.2	7.3
Bf1	0.91	6.4	0.52	55.5	38.9	5.5
Bf2	1.02	6.3	0.70	54.6	40.0	4.6
			Paleosol 2			
2Ah	2.05	6.3	0.81	51.6	45.7	2.6
2Bf1	1.21	6.3	0.53	66.6	30.7	2.6
2Bf2	0.78	6.5	0.29	64.1	31.0	4.8
			Paleosol 3			
3A	0.95	6.3	0.56	60.6	35.3	4.1
3AB	0.37	6.8	0.25	57.6	34.6	7.7
3Bf1	1.48	6.4	0.32	9.6	31.4	9.0
3Bf2	0.17	6.6	0.27	61.2	29.2	9.5
3R						
			Paleosol 4			
Bm	0.88	6.2	0.22	66.2	19.9	13.8
Bf1	1.02	6.3	0.62	67.6	20.3	12.0
Bf2	0.75	6.4	1.18	64.3	19.6	16.0
Bf3	0.67	6.4	0.31	78.5	10.0	11.4
3C	0.62	3.8	0.05	92.5	3.8	3.7

Table A3. Ammonium oxalate and sodium pyrophosphate extractable iron and aluminum in the Mount Nansen Podzolic paleosols.

Horizon	Ammonium oxalate (%)			Sodium pyrophosphate (%)		
	Fe	Al	Fe+Al	Fe	Al	Fe+Al
			Paleosol 1			
Ah	0.70	0.11	0.81	0.28	0.02	0.30
Bf1	1.31	0.11	1.42	0.14	0.01	0.15
Bf2	1.00	0.11	1.11	0.12	0.01	0.13
			Paleosol 2			
2Ah	0.19	0.10	0.29	0.04	0.01	0.05
2Bf1	1.13	0.08	1.21	0.21	0.01	0.22
2Bf2	1.12	0.09	1.21	0.16	0.01	0.17
			Paleosol 3			
3A	0.50	0.08	0.58	0.07	0.01	0.08
3AB	0.73	0.08	0.81	0.12	0.01	0.13
3Bf1	2.17	0.01	2.18	0.18	0.01	0.19
3Bf2	1.15	0.08	1.23	0.13	0.02	0.15
R	NA	NA	NA	NA	NA	NA
			Paleosol 4			
Bm	0.74	0.09	0.83	0.02	0.02	0.04
Bf1	2.81	0.04	2.85	0.62	0.01	0.63
Bf2	4.40	0.05	4.45	1.46	0.01	1.47
Bf3	1.07	0.11	1.18	0.36	0.06	0.42
3C	0.06	0.04	0.10	0.01	0.02	0.03

NA - not applicable

Table A4. Mineralogical analysis of Bf horizons from the Mount Nansen paleosols.

Soil	Horizon	Depth (cm)	ISM	Mica	Kaolinite	Amphiboles	Quartz	Microcline	Plagioclase	X-ray amorphous
Paleosol 1	Bf1	30-50		*	*		***	**	*	**
Paleosol 2	2Bf1	162-215		**	**	*	***	**	**	**
Paleosol 3	3Bf1	270-274	*	**	**	*	***	*	**	**
Paleosol 4	Bf2	180-192		****	****		***	**		tr
	Bf3	192-220		***	***		***	**	**	tr

ISM Interstratified minerals; * minor (1-10%); *** major (26-50%)
tr trace (<1%); ** moderate (11-25%); **** abundant (>50%)

Table A-5. Characteristics of the uppermost B horizons of the Mount Nansen paleosols.

Soil	Thickness (cm)[a]	Colour	Redness rating[b]	pH	C	$CaCO_3$ (%)	Oxalate extractable (%)[c]	Clay (%)[d]
Paleosol 1	26	7.5YR 5/6	3.0	6.4	0.52	0.91	1.42	5.5
Paleosol 2	53	7.5YR 5/6	3.0	6.3	0.53	1.21	1.21	2.6
Paleosol 3	136	7.5YR 6/6	2.5	6.4	0.32	1.48	2.18	9.0
Paleosol 4	81	7.5YR 7/8	2.9	6.3	0.62	1.02	2.85	12.0

[a] Total thickness of the B horizons.
[b] Redness rating = [(10-H)xC] /V, where H is the YR hue, C is the chroma, and V is the value (Torrent et al., 1980, 1983) based on Munsell soil colour charts.
[c] Ammonium oxalate extractable Fe+Al in the B horizon.
[d] Clay content of the B horizon.

slightly acid to neutral reaction (pH 6.3–6.8). The A horizon has a sandy loam texture and a low organic carbon content (0.56%). The two underlying Bf horizons also have sandy loam to silty textures, and the thickest Bf horizons (136 cm in total), with the 3Bf2 horizon (133 cm) being the thickest of all the individual Bf horizons.

Paleosol 4

This paleosol is very similar to, or slightly more developed than, paleosol 3. It also has thick Bf horizons (81 cm in total), with the highest amounts of ammonium oxalate extractable Fe+Al. The ammonium oxalate extractable Fe+Al in these three Bf horizons ranged from 1.18–4.45%. This paleosol is noncalcareous with a slightly acid reaction (pH 6.2–6.4). The A horizon has a sandy loam texture with a low organic carbon content (0.56%). The greatest amounts of kaolinite are found in this paleosol, suggesting an active and long period of weathering.

PALEOENVIRONMENTAL INTERPRETATION

The climate under which all of the Pony Creek paleosols were formed was drastically different than that of the Holocene or that of the Sangamonian (last) interglacial in central Yukon Territory. The only other paleosols that predate the Reid Glaciation in central Yukon Territory are the Wounded Moose paleosols (Tarnocai et al., 1985; Smith et al., 1986; Tarnocai, 1987; Tarnocai and Schweger, 1991). The Wounded Moose paleosols, however, occur below the 750 m elevation (Hughes et al., 1993) whereas the Pony Creek paleosols occur above 1000 m. The Pony Creek paleosol sequence provides an excellent opportunity for evaluating both the soil development above the 1000 m elevation and the associated climate during part of the pre-Reid–Reid interval.

The most important property of the Mount Nansen paleosols for interpreting past climates is the presence of well developed Bf (podzolic) horizons. Under the current climate, the nearest occurrence of such podzolic soil development is in the coastal areas of British Columbia. Soil temperatures in these areas seldom drop below 0°C, and when frost occurs, it affects only the soil surface. The presence of such podzolic soil horizons in the Mount Nansen area of central Yukon Territory thus indicates that the climate there was warmer and wetter during the soil-forming (interglacial) periods of the pre-Reid–Reid period than it is now.

The strong soil development and thick B horizons of paleosols 3 and 4 indicate that they probably developed in two different interglacial periods during the interval between the youngest of the pre-Reid glaciations and the Reid Glaciation. If periods of interglacial climate were long and warm enough during the pre-Reid–Reid interval, it is possible that all of these paleosols developed during one interglacial period. However, the strong soil development and deep weathering of paleosols 4 and paleosol 3 and the sterile and angular colluvium that separate them strongly suggest that they developed during separate interglacial periods. Paleosols 1 and 2 possibly developed during the same interglacial period. Whether or not one or two interglacial periods were involved, the formation of the youngest Pony Creek paleosol predated the Sangamonian (last) interglacial period. Soils formed during the Sangamonian interglacial were similar to, or only slightly better developed than, Holocene soils (Tarnocai and Valentine, 1989; Tarnocai, 1990).

SUMMARY AND CONCLUSIONS

Based on the soil development and soil properties, the past climates of the Mount Nansen area were reconstructed as follows:

1. The greater solum and B horizon thicknesses of paleosols 3 and 4 (the older paleosols) indicate that a longer time was available for soil formation than existed for paleosols 1 and 2. The decreased thicknesses of the latter two paleosols suggest that a shorter time was available for soil development and, thus, the time between burials was shorter than between paleosols 3 and 4.
2. The high amounts of ammonium oxalate extractable Fe+Al in the B horizons, when compared to the parent material, indicate strong soil development.
3. Podzolic soil development suggests that there were periods during the pre-Reid–Reid interval when climates were much moister and warmer than at the present time.

REFERENCES

Agriculture Canada Expert Committee on Soil Survey
1987: The Canadian System of Soil Classification; Agriculture Canada, Ottawa, Ontario, Publication 1646, 164 p. (2nd edition).

Duk-Rodkin, A., Barendregt, R.W., Tarnocai, C., and Phillips, F.M.
1996: Late Tertiary to late Quaternary record in the Mackenzie Mountains, Northwest Territories, Canada: stratigraphy, paleosols, paleomagnetism, and chlorine-36; Canadian Journal of Earth Sciences, v. 33, p. 875–895.

Foscolos, A.E., Rutter, N.W., and Hughes, O.L.
1977: The use of pedological studies in interpreting the Quaternary history of central Yukon; Geological Survey of Canada, Bulletin 271, 48 p.

Hughes, O.L., Tarnocai, C., and Schweger, C.E.
1993: Pleistocene stratigraphy, paleopedology, and paleoecology of a multiple till sequence exposed on the Little Bear River, Western District of Mackenzie, N.W.T., Canada; Canadian Journal of Earth Sciences, v. 30, p. 851–866.

Sheldrick, B.H.
1984: Analytical methods manual; Land Resource Research Institute, Agriculture Canada, L.R.R.I. Contribution No. 84-30, Ottawa, Ontario, 50 p.

Smith, C.A.S., Tarnocai, C., and Hughes, O.L.
1986: Pedological investigations of Pleistocene glacial drift surfaces in the central Yukon; Geographie physique et Quaternaire, v. 15, p. 29–37.

Tarnocai, C.
1987: Quaternary soils; *in* Guidebook to Quaternary Research in Yukon, (ed.) S.R. Morison and C.A.S. Smith (eds.); XII International Quaternary Association (INQUA) Congress, Ottawa, Canada, National Research Council of Canada, Ottawa, p. 16–23.
1990: Paleosols of the interglacial climates in Canada; Geographie physique et Quaternaire, v. 44, p. 363–374.

Tarnocai, C. and Schweger, C.E.
1991: Late Tertiary and early Pleistocene paleosols in northwestern Canada; Arctic, v. 44, p. 1–11.

Tarnocai, C. and Smith, C.A.S.
1989: Micromorphology and development of some central Yukon paleosols, Canada; Geoderma, v. 45, p. 145–162.

Tarnocai, C. and Valentine, K.W.G.
1989: Relict soil properties of the Arctic and Subarctic regions of Canada; *in* Paleopedology: Nature and Application of Paleosols, (ed.) A. Bronger and J. Catt; Catena Supplement, v. 16, p. 9–39.

Tarnocai, C., Smith, C.A.S., and Hughes, O.L.
1985: Soil development on Quaternary deposits of various ages in the central Yukon Territory; *in* Current Research, Part A; Geological Survey of Canada, Paper 85-1A, p. 229–238.

Torrent, J., Schwertmann, U., and Alferez, F.
1983: Quantitative relationships between soil colour and hematite content; Soil Science, v. 136, p. 354–358.

Torrent, J., Schwertmann, U., and Schulze, D.G.
1980: Iron oxide mineralogy of some soils of two river terrace sequences in Spain; Geoderma, v. 23, p. 191–208.

APPENDIX B

PALYNOLOGICAL REPORT NO. 89-15

R.J. Mott, Geological Survey of Canada
Terrain Sciences Divison, Quaternary Paleoecology Laboratory

Date: June 01/89
Locality: Mount Nansen area, about 46 km west of Carmacks, Yukon Territory
Latitude: 62°05′ N, **Longitude:** 137° 08′ W, **NTS:** 115-I
Submitted by: L.E. Jackson
Field No.: JJ-PAL-1, 2, 3, 5, 5A, 6
Lab. No.: PL-88-72
Description of samples: Slightly organic silts
Results and interpretation: The results of analysis are shown on Figure B-1.

The spectra found in samples 1, 2, and 3 contrast sharply with those of the other three samples analyzed. They are characterized by abundant sedge (Cyperaceae), and a variety of herb and shrub pollen with low amounts of tree pollen, particularly *Picea* (spruce). By contrast, samples 5A and 6 have high values for *Picea*. Sample 5 differs from the other spectra by having extremely high values for *Shepherdia canadensis* (Buffaloberry) pollen.

The results suggest a change from an open spruce forest or woodland to a shrub and herb tundra environment. The high *Shepherdia canadensis* values in sample 5 probably indicate local overrepresentation of this species. Buffaloberry often forms dense thickets in openings and dry forests and along rivers near the tree line. It may represent a time of transition from woodlands to tundra.

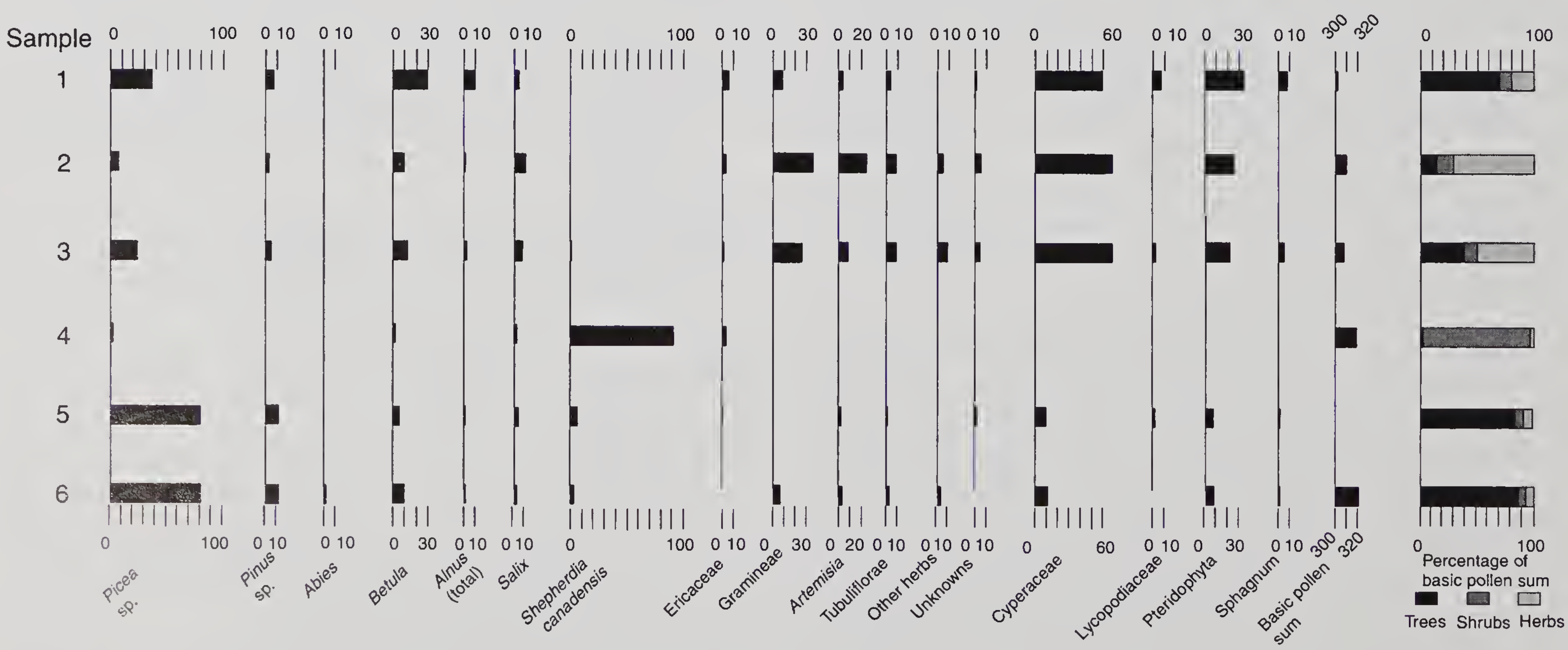

Figure B-1.

APPENDIX C

PALYNOLOGY OF REVENUE CREEK MAIN (DOWNSTREAM) AND UPSTREAM SECTIONS

REPORT PR-95.01

Hélène Jetté
Terrain Sciences Division

REPORT PR-95.01
Samples submitted by: L.E. Jackson
Samples P1 to P9
Samples were subsampled, identified with labels P1 to P9 and submitted to the Paleoecology Laboratory by A. Telka.
Laboratory procedures: The samples were submitted to standard palynological treatment: KOH, HF, HCl, acetic acid, acetolysis, sieving (15 µm), butanol, and storage in silicone oil. Pollen and spores were counted at a magnification of 40x to 100x.

REVENUE CREEK MAIN SECTION

This section comprises samples 1 to 9. The pollen diagram (*see* Fig. 28) has been compiled using the pollen of trees, shrubs, herbs, and unidentifyable palynomorphs. Spores are excluded from the sum. The pollen diagram has been divided into 3 zones: 1, 2, and 3, depending on the pollen content in the sediment.

Zone 1: samples P1, P2, P3, and P4

The assemblage of this zone is characterized mainly by 30 to 50% spruce (*Picea* sp.); from 10 to 20% birch (*Betula*); from 5 to 10% alder (*Alnus* sp.); 5% willow (*Salix*); about 5% of Ericaceae (heath family), grasses (Gramineae), and sedges (Cyperaceae); and by 15 to 60% *sphagnum*.

The pollen assemblages and the macrofossils reports indicate that two environments are present: forested areas and open areas (tundra). As the site is located in a valley, one possible scenario to explain the presence of the two different environments would be a forested valley with tundra at higher elevations. Other scenarios would be an open forest or patches of forest within a tundra.

All of the samples, except samples P5 and P6, contains charred remains, indicating forest fire activities (*see* Appendix D). Therefore samples P1 to P4 and P7 to P9 were probably deposited during periods of disturbance where organic material (macrofossils and pollen) were concentrated by erosion of the valley slopes.

It is difficult, therefore, to reconstruct the paleoenvironmental history of the site. As indicated by the spruce curve and by the macrofossil reports, the forest seems to have been denser at the time of the deposition of samples P2 and P3 whereas sample P4 is more representative of a shrub tundra. At the time that samples P2 and P3 were formed, the forest cover at the bottom of the valley possibly reached higher elevation than at the time of sample P1 and P4 formation. This points to a climatic cycle where sample P2 and P3 environments were warmer than those of samples P1 and P4.

Zone 2: samples P5 and P6

The assemblage of this zone is characterized by 25 to 50% sedges, from 20 to 10% sage (*Artemisia*), 10% grasses and by herbs such as Tubuliflorae, Liguliflorae, Caryophyllaceae, and Onagraceae. Spruce, birch, alder, and sphagnum are not present in the sediment.

The assemblage is a herb tundra, dominated by sedge and sage, indicative of cold and dry climate. Spruce, birch, and alder completely disappeared from the landscape.

As the tree-line position nowadays roughly corresponds to the mean July temperature isotherm of 10°C, the absence of spruce in P5 and P6 assemblages indicates colder summer temperatures, similar to the ones found today in Banks Island (6 to 8°C).

Zone 3: samples P7, P8, and P9

The assemblages of this zone are characterized mainly by 60 to 65% spruce, and by some 5 to 10% of birch, alder, and grasses. Sphagnum reaches 65%. Pollen concentration is similar to zone 1.

The environment is disturbed by forest fires. Sample P7 is peculiar in the sense that there is no sphagnum, indicating that the surrounding environment was not a peat bog, as opposed to zone 1 and to most of zone 3. In addition, there is a peak of Chenopodiaceae–Amaranthaceae at level P7, indicative of dry conditions. The climate is certainly warmer than previously (zone 2) but still dry (as in zone 2). The environment (P8) is a dense forest of spruce and birch. Peat, indicative of wetter conditions, developed later (samples 8 and 9). Trees were probably found at higher elevation than for zones 1 and 2.

Zone 3 is warmer than zone 2 and was probably warmer than zone 1.

It is not possible to determine if the climate at P2 time (zone 1) and of the entire zone 3 was warmer or similar than today. The samples are representative of disturbed environments and they are located at high elevations, at the bottom of a valley. One would need to carefully assess modern climate and forest cover at similar conditions (elevation, fires frequency, etc.) in southern Yukon Territory before an attempt can be made to characterize past climate. As the site is located in the middle of an ecotone, environmental changes are more likely to be detected by changes in the density of the forest cover rather than changes in the forests components.

The modern vegetation of southern Yukon Territory (Whitehorse Met station) is the "Boreal Northern Cordilleran Ecoclimatic Region". "Normal sites support communities of white spruce and feathermoss (*Hylocomium* spp.) which constitute the climax vegetation of the area. Drier sites support seral stands of lodgepole pine and trembling aspen, with understories of grass, lichen, Labrador tea, and bearberry. Black spruce, willow, Labrador tea, shrub birch, and moss are associated with poorly drained areas. Alluvial sites support stands of white spruce and balsam poplar, with understories of horsetail, rose, and alder. This ecoclimatic region usually occupies lower slopes and valley bottoms". The mean July temperature varies between 12.5 and 15°C (Environment Canada, 1989).

Pine is present today in southern Yukon Territory but arrived late during the Holocene. Its absence in the fossil sequence does not necessarily mean a colder environment than today, it may be due to a migration.

REVENUE CREEK UPSTREAM SECTION

REPORT PR-95.02
Samples submitted by: L.E. Jackson
Samples P11–P15
Samples were subsampled, identified with labels P11 to P15 and submitted to the paleoecology laboratory by A. Telka. Laboratory procedures as in report PR-95.01.

The pollen diagram (Fig. 28) has been compiled using the pollen of trees, shrubs, herbs, and unidentiriable palynomorphs. Spores are excluded from the sum. The pollen diagram has been divided into 3 zones: 1, 2, and 3, depending on the pollen content in the sediment.

Zone 1 is characterized by 10 to 30% grasses, 15% sages (*Artemisia*), 5 to 10% Caryophyllaceae, and 20 to 40% sedges. The environment is a herb tundra and the climate is cold and dry.

Zone 2 is characterized by 15% willow (*Salix*), more than 30% grasses, and 15% sages and sedges. The environment is a shrub tundra. The climate is still cold and dry but it is warmer than for zone 1.

Zone 3 is characterized by 40% grasses, 5% Tubuliflorae, 10 to 5% sages (*Artemisia*), 5% Caryophyllaceae, and 20 to 60% sedges. The environment is a herb tundra, colder than zone 2 but quite similar to the one characterizing zone 1.

The upstream section is characterized by a climatic cycle, zone 1 is cold (herb tundra), zone 2 warmer (shrub tundra), and zone 3 cold again (herb tundra). An ice wedge is reported by L.E. Jackson to be present in the upper part of zone 3.

REFERENCE

Environment Canada
1989: Ecoclimate regions of Canada; Environment Canada Ecological Land Classification Series, no. 23, 118 p.

APPENDIX D

MACROFOSSIL IDENTIFICATIONS

Alice Telka, Terrain Sciences Division
Geological Survey of Canada

MACROFOSSIL REPORT: MFRPT 94-101

Sample No.: JJO-05-07-89-P1
Lab No.: 12-47
Locality: Revenue Creek placer mine, Y.T. Deep excavation through muck and valley gravels. Gravel deposition nonglacial but some erratics found at bottom of valley on bedrock.
Latitude: 62°20.22′ N **Longitude:** 137°16.35′ W **Elevation:** 630 m
Collected by: Lionel Jackson
Submitted by: Lionel Jackson
Stratigraphic unit: Fluvial deposit with angular, poorly sorted gravel. Organic detritus incorporated into gravel.
Material: Thinly bedded organic rich silt. Beds lensoidal and don't persist any more than 30 cm. Sampled immediately above lowest gravel 10.7 m.

Key: + = taxon present, ++ = taxon common, +++ = taxon abundant

ANIMAL MACROFOSSILS:

TUBELLARIA ...."flatworms"	+	cocoons
OLIGOCHAETA		
Lumbricidae ...."earthworms and aquatic worms"	+	possible cocoon
ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	legs
Carabidae ...."ground beetles"	+	worn head fragment, pronotum
Pterostichus sp.	+	heads
Pterostichus (Cryobius) caribou type	+	pronotum
Pterostichus (Cryobius) sp.	+	trochanter
Byrrhidae ...."pill beetles"		
Simplocaria sp.	+	pronotum
Bostrichidae........."branch-twig borer beetles"	+	pronotum, possible head fragment
Curculionidae ....."weevils"		
Apion sp.	+	pronotum
Lepidophorus lineaticollis Kirby	++	elytra (right and left attached), pronotum, heads
Scolytidae ...."bark beetles"	+	head fragment, pronotum
DIPTERA ...."flies"	+	puparia-few types, adult fragments
HYMENOPTERA ...."wasps and ants"	+	adult thorax and abdomen
Ichneumonoidea ...."ichneumons and braconids"		
Ichneumonidae	+	thoracic propodium
Formicidae ...."ants"	+	mandible
Formica type	++	heads, pedicels
Camponotus sp.	+	heads
ARACHNIDA		
Oribatei/Acari ...."mites"	>50	several kinds
Cepheoidea		
Cepheus type	+	
Araneae ...."spiders"	+	palp with setae intact
Unidentifiable animal taxa	+	misc. fragments

PLANT MACROFOSSILS:

Fungi:		
Fungal Sclerotia	+++	medium to large size
Vascular plants:		
Pinaceae ...."pine family"		
Picea sp.	+++	seeds, needles, charred needle fragments
Picea mariana (Mill.)	+	charred needle fragments
Cyperaceae ...."sedge family"		
Carex spp.	++	trigonous & lenticular type, 2 charred seeds
Juncaceae ...."rush family"		
Juncus/Luzula type	+	seeds
Caryophyllaceae ..."pink family"	+	seed
Ericaceae ...."heath family"		
Empetrum nigrum L.	+++	seeds, two sizes, some attached
Arctostaphylos uva-ursi (L.) Spreng.	+	seed
Unidentified plant taxa	+	seeds
Other:		
Wood	+++	some charred pieces, some with bark, some flat with rounded angular ends
Rhizome	+	stem fragments

COMMENTS

The organic residue in this sample consists mainly of wood and bark fragments including charred wood. The most abundant fossils are fungal sclerotia, spruce needles, crowberry *(Empetrum nigrum)*, mites, and ants. Some of the macrofossils are charred including spruce needles, and crowberry and sedge seeds suggesting a fire ocurred at or near the site.

Several of the fossils listed on the previous page live within a forest. The ocurrence of Scolytidae, commonly known as bark or engraver beetles, is rarely seen as a fossil. These beetles live under bark of trees mining the surface while others bore into the wood creating characteristic tunnels. Bostrichidae, another rarely seen fossil, is a branch and twig borer beetle which attacks living trees and dead twigs and branches. The mite *Cepheus* is commonly found in thick forest litter. Ant fossils are also abundant in this sample including the large carpenter ant, *Camponotus*.

Although most of the insect fossils found in this sample indicate a forested environment, *Pterostichus (Cryobius) caribou*, a ground beetle that lives on wet and dry tundra on peaty or sandy soil (Ball, 1966), is incompatible with the rest of the fossil assemblage. However this situation is not unusual in Yukon Territory, and Old Crow fossils have yielded both tundra fossils with spruce fossils. There is no modern day analogue for this type of environment. If this is not the case, this sample may contain rebedded material.

The most abundant plant fossil remains are spruce needles, fungal sclerotia, and crowberry seeds *(Empetrum nigrum)*. Due to the great number of spruce fossils in this sample, not all were picked. They include many charred needles. The abundance of fungal sclerotia in this sample suggests a soil. The abundant crowberry seeds found in the sample P1 organics are berries which commonly grow in sandy, rocky, acidic soils (Porsild and Cody, 1980).

The combined fossil evidence of both insects and plants suggests a forested environment with abundant spruce. Within the spruce forest are open areas where plants like crowberries can survive in acidic soils. All of the fossils examined in this sample can be found living in Yukon Territory today.

REFERENCES

Ball, G.E.
1966: A revision of the North American species of the subgenus *Cryobius* Chaudoir (*Pterostichus*, Carabidae, Coleoptera); Opuscula Entomologica Supplementum XXVIII, 166 p.

Porsild, A.E. and Cody, W.J.
1980: Vascular plants of continental Northwest Territories, Canada; National Museums of Canada, Ottawa, Ontario, 667 p.

MACROFOSSIL REPORT: MFRPT 94-102

Sample No.: JJO-05-07-89-P2

Lab No.: 12-48
Locality: Revenue Creek placer mine, Y.T. Deep excavation through muck and valley gravels. Gravel deposition nonglacial but some erratics found at bottom of valley on bedrock.
Latitude: 62°20.22′ N **Longitude:** 137°16.35′ W **Elevation:** 630 m
Collected by: Lionel Jackson
Submitted by: Lionel Jackson
Stratigraphic unit: Fluvial deposit with angular, poorly sorted, thinly bedded gravel interstratified with organic-rich silt and wood fragments. Gravel matrix has a high organic content.
Material: Thinly bedded organic-rich silt. Beds lensoidal and do not persist anymore than 30 cm. Sampled approximately 10.5 m below surface.

Key: + = taxon present, ++ = taxon common, +++ = taxon abundant

ANIMAL MACROFOSSILS:

TUBELLARIA ...."flatworms"	+	cocoons
ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"		
Carabidae ...."ground beetles"	+	elytron
Pterostichus (Cryobius) hudsonicus Lec.	+	pronotum
Pterostichus (Cryobius) brevicornis Kby.	+	pronota: one fired hardened articulated
Pterostichus Cryobius sp.	+	elytra, head
Staphylinidae ....."rove beetles"	+	elytron
Olophrum latum Makl.	+	elytron, pronotum
Aleocharinae	+	head, prothorax
Leiodidae ...."round fungus beetles"		
Agathidium sp.	+	elytron
Byrrhidae ...."pill beetles"		
Simplocaria sp.	+	elytron fragment
Chrysomelidae ....."leaf beetles"	+	head
Curculionidae ....."weevils"	+	elytral fragment
Lepidophorus lineaticollis Kirby	+	elytra
LEPIDOPTERA ...."butterflies/moths	+	larval head capsule
DIPTERA ?............"flies"	+	puparia – few types, head
Tipulidae ...."crane flies"	+	ovipositor
HYMENOPTERA ...."wasps and ants"		
Formicidae ...."ants"		
Formica sp.	++	heads, pedicels, mandibles
Camponotus?	+	heads
ARACHNIDA		
Oribatei/Acari ...."mites"	+++	several kinds
Cepheoidea		
Cepheus type	++	
Araneae ...."spiders"	+	palps
Other:		
Fecal pellets	++	

PLANT MACROFOSSILS:

Fungi:		
Fungal Sclerotia	+++	small and large sized, attached in a group
Actinorhizal rhizomes	+	stems
Bryophytes ...."mosses"	+++	fragments, same type – *Sphagnum*?
Vascular plants:		
Pinaceae ...."pine family"		
Picea sp.	+++	charred and uncharred: seeds, needles
Cyperaceae ...."sedge family"		
Carex sp.	+++	seeds: one charred, trigonous type, some with perigynium and stigmas
Juncaceae ...."rush family"		
Juncus/Luzula sp.	+++	seeds
Ericaceae ...."heath family"		
Empetrum nigrum L.	++	seeds: one charred, others uncharred
Unidentified macrofossil taxa	+	
Other:		
Wood	+	small fragments: charred or uncharred, some with bark

COMMENTS

The fine organic fraction of this sample consists mostly of small wood fragments, charred wood, and mosses. Plant macrofossils are abundant including many fungal sclerotia, mosses, spruce, sedges, and rushes. Spruce needles and mosses are by far the most abundant fossils in this sample. This sample, like P1 contains charred fossils suggesting a fire occurred at or near the site.

The most abundant animal fossils are ants, including possibly the carpenter ant *Camponotus*, and mites. Among the mites, *Cepheus* a forest litter mite, is abundant. In this sample, insect fossils of *Pterostichus (Cryobius) hudsonicus* and *Pterostichus (Cryobius) brevicornis* occur. These ground beetles live in the woods near openings more often near or below tree line. All of these fossils indicate a forested environment.

This sample also contains a fossil of the rove beetle *Olophrum latum*. These beetles have been collected from clumps of emergent subaquatic vegetation (particularily sedges) growing in shallow water (Campbell, 1983).

The presence of many ants in this sample indicates a dry environment. This is contradictory to the plant fossil evidence which suggests a predominately wet environment. However, with the presence of charred wood, the large number of ants may be attributed to the fact that ants are known to invade freshly burned forested areas.

As indicated above, the plant fossils in this sample (excluding spruce) suggest a wet environment. The sedges are abundant and well preserved and include the wetland variety, trigonous-type seeds. Sample P2 is the only sample to contain abundant mosses (same kind) and they should be further identified.

Similar to P1, this sample also contains crowberry fossil seeds of *Empetrum nigrum* which suggests dry, acidic soil type environment. There is also a lot of fungal sclerotia, indicative of a soil.

In conclusion, the fossil assemblage in sample P2 suggests a mixture of two environments. It is predominantly a wet environment with submergents such as sedges growing surrounded by mosses and rushes with trees (spruce) growing nearby. All of the fossils listed in this report can be found living in Yukon Territory today.

REFERENCE

Campbell, J.M.
1983: A revision of the North American Omaliinae (Coleoptera: Staphylinidae). The genus *Olophrum* Erichson; The Canadian Entomologist, v. 115, no. 6, p. 577–622.

MACROFOSSIL REPORT: MFRPT 94-103

Sample No.: JJO-05-07-89-P3
Lab No.: 12-49
Locality: Revenue Creek placer mine, Y.T. Deep excavation through muck and valley gravels. Gravel deposition nonglacial but some erratics found at bottom of valley on bedrock.
Latitude: 62°20.22′ N **Longitude:** 137°16.35′ W **Elevation:** 630 m
Collected by: Lionel Jackson
Submitted by: Lionel Jackson
Stratigraphic unit: Fluvial deposit with thinly bedded rusty angular gravel interstratified with organic-rich silt.
Material: Organic-rich silt in rusty red gravels 10.3 m below surface.

Key: + = taxon present, ++ = taxon common, +++ = taxon abundant

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"		
Carabidae ...."ground beetles"		
Bembidion grapeii group	+	elyron fragment
Pterostichus (Cryobius) hudsonicus? Lec.	+	pronotum
Pterostichus (Cryobius) brevicornis Kby.	+	pronota, head
Pterostichus (Cryobius) nivalis F. Sahlb.	+	pronota
Pterostichus Cryobius sp.	+	pronotum and elytron fragments
Hydraenidae ...."minute moss beetles"		
Ochthebius sp.	+	fragment
Staphylinidae ....."rove beetles"		
Stenus sp.	+	thoracic segment
Aleocharinae	+	thoracic segment
Byrrhidae ...."pill beetles"		
Byrrhus sp.	+	elytron fragment
Bostrichidae........."branch-twig borer beetles"	+	elytron
Cryptophagidae.... “silken fungus beetles”	+	elytron fragment
Lathridiidae ...."minute brown scavenger beetles"	+	elytron fragment
Curculionidae ....."weevils"	+	elytral fragment
Lepidophorus lineaticollis Kirby	+	head, prothorax, elytral fragments
Scolytidae ...."bark beetles"		
Carphoborus? sp.	+	elytron
LEPIDOPTERA ...."butterflies/moths	+	larval head capsules
DIPTERA ?............"flies"	+	puparium fragment
ARACHNIDA		
Oribatei ...."oribatid mites"	+	
Cepheoidea		
Cepheus type	++	
Araneae ...."spiders"	+	cephlathorax

PLANT MACROFOSSILS:

Fungi:		
Fungal Sclerotia	++	attached in a group
Vascular plants:		
Pinaceae ...."pine family"		
Picea sp.	+++	charred needles (80%) and charred cone scales
Cyperaceae ...."sedge family"		
Carex spp.	+	trigonous-type seeds; charred, two sizes
Rosaceae ...."rose family"		
Rubus idaeus L.	+	seed
Ericaceae ...."heath family"		
Empetrum nigrum L.	+	seed
Other:		
Wood	+	charred and uncharred pieces

COMMENTS

This sample contains relatively less organic material compared to the other samples examined from Revenue Creek. The organic residue consists of mainly small fragments of wood, including charred wood and plant fragments. The most abundant fossil is spruce and this sample contains the greatest number of charred needles and cone scales seen in any of the Revenue Creek samples. Fire has ocurred at or very near the site.

Most of the insect fossils in this sample indicate a forest-type environment. It contains the rarely seen bark (Scolytidae) and branch twig borer (Bostrichidae) beetle fossils. Both of these beetles either live under bark of trees burrowing in them or attack living and dead trees. *Cepheus* mites are abundant. These mites live on the forest floor in thick leaf litter. There are also insect fossils in this sample which live at the margin of woods in openings such as the ground beetles *Pterostichus (Cryobius) hudsonicus* and *Pterostichus (Cryobius) brevicornis*.

There is one incompatible insect fossil in this assemblage, the ground beetle *Pterostichus (Cryobius) nivalis*. This beetle is a tundra beetle. However this situation is not uncommon in Yukon Territory and one can often find both tundra fossils associated with spruce fossils. There is no modern-day analogue for this type of environment.

The plant fossils in this sample, excluding spruce, are less abundant compared to other samples. They include raspberries *(Rubus idaeus)* which commonly grow in marginal areas of a forest and the crowberries *(Empetrum nigrum)* which lives in open areas on acidic soils.

In summary, the macrofossils in this sample indicate a forested environment with openings allowing plants like berries to grow. All of the fossil types encountered in this sample can be found living in Yukon Territory today.

MACROFOSSIL REPORT: MFRPT 94-104

Sample No.: JJO-05-07-89-P4
Lab No.: 12-50
Locality: Revenue Creek placer mine, Y.T. Deep excavation through muck and valley gravels. Gravel deposition nonglacial but some erratics found at bottom of valley on bedrock.
Latitude: 62°20.22′ N **Longitude:** 137°16.35′ W **Elevation:** 630 m
Collected by: Lionel Jackson
Submitted by: Lionel Jackson
Stratigraphic unit: Fluvial deposit with interbedded organic-rich silt and pebble gravels.
Material: Organic-rich layer 8.47 m below surface.

Key: + = taxon present, ++ = taxon common, +++ = taxon abundant

ANIMAL MACROFOSSILS:

TUBELLARIA? ....”Flatworms”	+	cocoon
ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"		
Carabidae ...."ground beetles"	+	elytral fragments, prosternums, heads – one is poorly preserved
Notiophilus sylvaticus Eschz.	+	right elytron-basal fragment
Pterostichus sp.	+	heads, prothoracic fragments, elytral fragments, elytra
Pterostichus (Cryobius) brevicornis? Kby.	+	prothorax, right and left elytron
Pterostichus Cryobius sp.	+	left elytron
Trichocellus sp.	+	head
Staphylinidae ....."rove beetles"	+	right elytron, pronotum
Aleocharinae	+	right elytron, fragment of pronotum
Cryptophagidae?.... "silken fungus beetles"	+	left elytron
Curculionidae ....."weevils"	+	heads
Lepidophorus lineaticollis Kirby	+	prothorax, articulated prothorax, heads
Scolytidae ...."bark beetles"	+	elytra
LEPIDOPTERA ...."butterflies/moths"	++	larval head capsules: same type
DIPTERA ?............"flies"	+	puparium fragments
ARACHNIDA		
Oribatei ...."oribatid mites"	+	

Araneae ...."spiders"	+	fragment
Other:		
Insect ovipositors	++	
Rodent feces?	+	

PLANT MACROFOSSILS:

Fungi:		
Fungal Sclerotia	+	
Vascular plants:		
Pinaceae ...."pine family"		
Picea sp.	+++	charred and uncharred needle fragments, charred cone scales
Cyperaceae ...."sedge family"		
Carex trigonous type	+	seeds
Salicaceae ...."willow family"		
Salix? sp.	+	twig fragments
Rosaceae ...."rose family"		
Rubus idaeus L.	++	whole and half seeds
Unidentifiable plant taxa	+	seeds
Other:		
Wood	+++	charred and uncharred pieces

COMMENTS

The organic component in this sample consists of mainly fine wood fragments including charred wood. Unlike samples P1 to P3 which were very abundant in spruce needles, this sample contains fewer spruce fossils and more seed fossils of raspberries *(Rubus idaeus).*

The insect fossils in this sample include such insects as *Notiophilus sylvaticus*, a ground beetle which lives on shaded gravelly ground in sparse woods and *Trichocellus*, another ground beetle which also lives in forested areas occurring on open or thinly wooded places. As seen in other samples, this sample also contains the bark beetle Scolytidae which inhabit forests.

This sample also contains a large number of butterfly or moth (Lepidoptera) larval head capsules of the same kind.

The combined plant and animal fossil evidence in this sample suggests a thinly wooded spruce forest environment with marginal type plants growing in the understory of open spaces. All of the fossils in the sample can be found living in Yukon Territory today.

MACROFOSSIL REPORT: MFRPT 94-105

Sample No.: JJO-05-07-89-P5
Lab No.: 12-51
Locality: Revenue Creek placer mine, Y.T. Deep excavation through muck and valley gravel. Gravel deposition nonglacial but some erratics found at bottom of valley on bedrock.
Latitude: 62°20.22′ N **Longitude:** 137°16.35′ W **Elevation:** 630 m
Collected by: Lionel Jackson
Submitted by: Lionel Jackson
Stratigraphic unit: Fluvial deposit with interbedded organic-rich silt and pebble gravel units.
Material: Organic-rich layer 8.17 m below surface.

Key: + = taxon present, ++ = taxon common

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"		
Carabidae ...."ground beetles"	+	fragments: head, elytral, sternum, leg
Pterostichus sp.	+	right elytron
Bembidion sordidum Kby. Group	+	right elytron, prosternum
Pterostichus (Cryobius) ventricosus Eschz.	+	left elytron, pronotum-worn, thin edges
Pterostichus (Cryobius) sp.	+	elytra-intact
Amara (Curtonotus) sp.	+	basal half left elytron, elytron
Amara sp.	+	elytron fragments
Curculionidae ....."weevils"	+	elytral fragments, sternum
Lepidophorus lineaticollis Kirby	+	elytral fragments, pronota
DIPTERA ...."flies"	+	pupa fragment

PLANT MACROFOSSILS:

Vascular plants:		
Cyperaceae ...."sedge family"		
Carex sp.	++	stem fragments, seeds, two types
Ranunculaceae ....."crowfoot family"		
Ranunculus abortivus L.	+	seeds
Other:		
Wood	+	

COMMENTS

For this sample, only the larger organic fraction (greater than 850 µm) was examined. This sample contains abundant organic residue consisting mostly of small wood and vegetative fragments. Unlike samples P1–P4, this sample has no charred fossils.

The insect fossils by far outnumber the plant fossils in this sample. The preservation of the insect fossils is relatively poor with worn, thin edges.

In examining the plant fossils, noteworthy is the absence of trees especially spruce as seen in most of the Revenue Creek samples. Instead there are more sedges of the nonaquatic type.

The fossil evidence in this sample suggests a dry sedge terrain. All of the fossils in this sample can be found living in Yukon Territory today with the buttercup *(Ranunculus abortivus)* being at its northern limit.

MACROFOSSIL REPORT: MFRPT 94-106

Sample No.: JJO-05-07-89-P6
Lab No.: 12-52
Locality: Revenue Creek placer mine, Y.T. Deep excavation through muck and valley gravels. Gravel deposition nonglacial but some erratics found at bottom of valley on bedrock.
Latitude: 62°20.22′ N **Longitude:** 137°16.35′ W **Elevation:** 630 m
Collected by: Lionel Jackson
Submitted by: Lionel Jackson
Stratigraphic unit: Fluvial deposit with thinly bedded decomposed silty peat and silt.
Material: Silty peat 5.9 m below surface.

Key: + = taxon present

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
HOMOPTERA		
Aphididae..............."aphids or plant lice"	+	modern contaminant
COLEOPTERA ...."beetles"		
Carabidae ...."ground beetles"	+	elytral fragment, sternite
Bembidion morulum/(Trepanedoris) group	+	pronotum
Pterostichus (Cryobius) sp.	+	elytral fragment
Curculionidae ....."weevils"	+	elytron
Lepidophorus lineaticollis Kirby	+	pronotum, elytron, elytral fragments
LEPIDOPTERA ...."butterflies/moths"	+	larval head capsule
DIPTERA ...."flies"	+	pupae fragments of same type
ARACHNIDA		
Oribatei ...."oribatid mites"	+	
Unidentifiable animal taxa	+	miscellaneous fragments
Other:		
Rodent feces	+	whole pellets

PLANT MACROFOSSILS:

Bryophytes...."mosses"	+	stems without leaves
Vascular plants:		
Cyperaceae ...."sedge family"		
Carex spp.	+	seeds, three types but mostly lenticular
Chenopodiaceae ...."goosefoot family"		
Chenopodium sp.	+	seed fragments, seed (poorly preserved)
Rosaceae ...."rose family"		
Potentilla sp.	+	seed
Other:		
Wood fragments	+	small fragments
Fungal spheres	+	hollow internally

COMMENTS

For this sample, only the larger sized organic fraction (>850 µm) was examined. This sample contains a lesser amount of organic material compared to sample P5 from the same unit. They comprise mostly small wood and vegetative fragments. Unlike samples P1–P4, this sample has no charred fossils.

The fossils in this sample are very similar to those of sample P5. Once again there is the absence of spruce and the presence of sedges along with goosefoot plants. There is also evidence of mosses however they are rare.

The insect fossil-*Bembidion morulum/(Trepanedoris)* group requires further determination if this sample proves to be significant. This ground beetle of the *B. (Trepanedoris)* group lives near water whereas *B. morulum* does not.

The fossil evidence in this sample is very similar to that in sample P5 and suggests a dry sedge-type terrain with a few mosses and scattered goosefoot plants growing. All of the fossil types encountered in this sample can be found living in Yukon Territory today.

MACROFOSSIL REPORT: MFRPT 94-107

Sample No.: JJO-05-07-89-P7
Lab No.: 12-53
Locality: Revenue Creek placer mine, Y.T. Deep excavation through muck and valley gravel. Gravel deposition nonglacial but some erratics found at bottom of valley on bedrock.

Latitude: 62° 20.22′ N **Longitude:** 137° 16.35′ W **Elevation:** 630 m
Collected by: Lionel Jackson
Submitted by: Lionel Jackson
Stratigraphic unit: Fluvial deposit with angular to subrounded rusty gravel containing lenses of peaty organicmaterial and pieces of wood.
Material: Silty peat 4.9 m below surface.
Other: ^{14}C ages of >38 000 BP (GSC-4963) and >40 000 BP (GSC-4935) from spruce logs near the top of the section.

Key: + = taxon present, ++ = taxon common, +++ = taxon abundant

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"		
Carabidae ...."ground beetles"	+	mandible
Dyschiriodes sp.	+	head, right elytron
Staphylinidae ....."rove beetles"		
Quedius sp.	+	head
Tachyporus sp.	+	right elytron
Leiodidae.........."round fungus beetle"	+	elytral fragment
Bostrichidae?........."branch-twig borer beetles"	+	pronotum
Chrysomelidae? ....."leaf beetles"	+	'fire-hardened' head and prothorax
Curculionidae ....."weevils"	+	elytral fragment
Lepidophorus lineaticollis Kirby	+	elytral fragments, pronotum
Scolytidae ...."bark beetles"	+	right elytron, pronotum
LEPIDOPTERA ...."butterflies/moths"	+	larval head capsules
DIPTERA ...."flies"	+	pupae including fragments, few kinds
ARACHNIDA		
Oribatei ...."oribatid mites"	+	
Cepheoidea		
Cepheus type	+	
Araneae ...."spiders"		
Erigone? sp.	+	male spider cephlathorax
Unidentifiable animal taxa	+	miscellaneous fragments
Other:		
Rodent feces	+	half pellets

PLANT MACROFOSSILS:

Fungi:		
Fungal Sclerotia	+	
Vascular plants:		
Pinaceae ...."pine family"		
Picea sp.	+++	needles: fragment and whole, some charred; cone scales with seeds
Picea mariana ...."black spruce"	+	charred needle fragment
Cyperaceae ...."sedge family"		
Carex trigonous type	++	seeds
Carex lenticular type	+	seed
Salicaceae ...."willow family"		
Salix? sp.	+	leaf fragment
Rosaceae ...."rose family"		
Rubus idaeus L.	+	seeds

Ericaceae ...."heath family"		
Empetrum nigrum L.	+	seeds
Other:		
Wood fragments	+++	some are charred
Rhizomes	+	stems

COMMENTS

The organic component of sample P7 is large comprising about half the volume (1000 mL) of the original sample submitted. Among the organic residue are wood fragments including abundant charred wood and fine plant fragments. Approximately 5% of the macrofossils are charred including mostly spruce needles and an articulated 'fire-hardened' leaf beetle. As seen in most of the Revenue Creek samples examined, there is evidence of a fire occurring at or near the site.

The insect fossils include many forest-type insects. There is the bark beetle Scolytidae which live in trees under bark and *Cepheus* mites which live in forest leaf litter. A rarely seen fossil, the round fungus beetle (Leiodidae), appears in this sample. It is a beetle which lives in fungi, under bark, and in decaying wood.

The most abundant plant fossils in this sample are spruce needles including some charred fragments and seeds with wings intact. It is from the charred fragments that black spruce (*Picea mariana*) can be confidently identified. This sample also contains abundant fossil seeds of sedges of the submergent, aquatic type. Crowberry *(Empetrum nigrum)* fossils seeds are also fairly abundant. This plant is commonly found in dry acidic soils.

This sample contains a mixture of two environments. The environment is predominatly forested with spruce growth allowing for open areas where crowberry plants can grow in acidic soils. There is also evidence of a wet environment in which sedges are growing in small, wet depressions. All the fossils examined in this sample can be found living in the Yukon Territory today.

MACROFOSSIL REPORT: MFRPT 94-108

Sample No.: JJO-05-07-89-P8
Lab No.: 12-54
Locality: Revenue Creek placer mine, Y.T. Deep excavation through muck and valley gravel. Gravel deposition nonglacial but some erratics found at bottom of valley on bedrock.
Latitude: 62°20.22′ N **Longitude:** 137°16.35′ W **Elevation:** 630 m
Collected by: Lionel Jackson
Submitted by: Lionel Jackson
Stratigraphic unit: Fluvial deposit with angular to subrounded rusty gravel containing lenses of peaty organic material and pieces of wood.
Material: Peaty lens in angular rusty gravels 3.2 m below surface.
Other: ^{14}C ages of >38 000 yrs. BP (GSC-4963) and >40 000 yrs. BP (GSC-4935) from spruce logs near the top of the section.

Key: +=taxon present, ++= taxon common, +++=taxon abundant

ANIMAL MACROFOSSILS:

PORIFERA ...."sponges"		
HAPLOSCLERINA		
Spongillidae		
Spongilla type?	+	capsules
ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	articulated legs
Carabidae ...."ground beetles"		
Trechus apicalis Motsch.	+	elytron
Pterostichus(Cryobius) sp.	+	right and left elytra
Staphylinidae ....."rove beetles"		

Olophrum sp.	+	head
Byrrhidae ...."pill beetles"		
Curimopsis sp.	+	elytron
Curculionidae ....."weevils"		
Lepyrus sp.	+	head
Scolytidae ...."bark beetles"	+	heads
LEPIDOPTERA ...."butterflies/moths"	+	larval head capsules
DIPTERA ...."flies"	+	pupae fragments, two kinds
Chironomidae ......"midges"	+	larval head capsules
HYMENOPTERA ...."wasps and ants"		
Formicidae ...."ants"	+	heads, mandible
ARACHNIDA		
Oribatei/Acari........."mites"	++	
Cepheoidea		
Cepheus type	+	
Unidentifiable animal taxa	+	miscellaneous fragment
Other:		
Rodent feces	+	pellets/fragments
Net-like object	+	fragment

PLANT MACROFOSSILS:

Picea sp.	+++	needles – more whole then fragments, some charred; seeds – with and without wings
Fungi:		
Fungal Sclerotia	+++	small and large
Bryophytes ...."mosses"	+	fragments, *Sphagnum?*
Vascular plants:		
Pinaceae ...."pine family"		
Cyperaceae ...."sedge family"		
Carex trigonous type	+	seeds, one is charred
Salicaceae ...."willow family"		
Salix sp.	+	capsule
Juncaceae ...."rush family"		
Juncus/Luzula sp.	+	seeds-two types
Betulaceae ...."birch family"		
Alnus crispa? Ait(Pursh.)	+	seeds
Alnus incana (L.)Moench.	+	seed
Alnus sp.	+	seeds
Betula aboreal type	+	bracts, seed
Betula sp. medium shrub type	+++	seeds
Chenopodiaceae ...."goosefoot family"		
Chenopodium sp.	+	seed
Papaveraceae ......"poppy family"		
Papaver sp.	+	seed
Rosaceae ...."rose family"		
Potentilla sp.	+	seeds
Rubus idaeus L.	+	seeds
Violaceae ...."violet family"		
Viola sp.	+	seed
Ericaceae ...."heath family"		
Empetrum nigrum L.	+	seeds
Unidentifiable plant taxa	1	seed
Other:		

Wood	++	fragments, 2.5 cm long, with and with out bark, some pieces are worn
Rhizome	11	stem fragments

COMMENTS

This report is an update to include the results obtained from AMS dating of an alder (*Alnus*) cone. A 1.3 cm long cone weighing 30.8 mg was submitted to Beta Analytic and dated by Lawrence Livermore Lab. A nonfinite date of >53 990 BP (Beta-90218) was obtained.

Fossils in this sample are well preserved and numerous. The organic fraction consists of mostly wood fragments, some charred wood, mosses, and plant fragment remains. The presence of charred fossils, mostly spruce needles, indicates a fire has occurred at or nearby the site.

Insect fossils are abundant as evidenced by the large number of mites (~150) including *Cepheus,* a mite which lives in forest floor litter. This sample also contains fossils of the bark beetle, Scolytidae another forest insect that lives under bark of trees. The weevil *Lepyrus*, a beetle which feeds on willow also occurs in this sample. Unique to this sample is the presence of aquatic animals, that is fossils of larval midges (Chironomidae) and freshwater sponges (requires confirmation of identification). Two other insect fossils present in this sample also indicate a damp environment. The pill beetle *Curimopsis* lives in the boreal forest and arctic regions in areas of fine, moist, matted mosses on sandy soils (Johnson, 1986). *Trechus apicalis* is a ground beetle which lives in damp environments occurring on gravelly, peaty soil among dead leaves in the understory of bushes (Lindroth, 1963).

The most abundant plant fossils are spruce needles, birch seeds and bracts, fungal sclerotia, and raspberry and crowberry seeds.

This sample, compared to samples P1–P7, is the only one to contain birch including abundant large tree type. Raspberries *(Rubus idaeus)* are plants that live in the margins of trees. The heath plant *(Empetrum nigrum)* grows in acidic soils. Mosses (same species) are also fairly abundant compared to other Revenue Creek samples. These should be identified to see if they contain *Sphagnum.*

The combined plant and animal fossil evidence suggests a mixture of two environments. The predominant environment is a dense forest where spruce and birch trees are growing. Fossil evidence also indicates the presence of a small pond with mosses, sedge, and rush plants growing along the margins. All of the fossils in this sample exists today in Yukon Territory.

REFERENCES

Johnson, P.J.
1986: A new species and key to the nearctic species of *Curimopsis* Ganglbauer (Coleoptera: Byrrhidae); The Coleopterists Bulletin, v. 40, no. 1, p. 37–43.

Lindroth, C.H.
1963: The Ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska, Pt. 3; Opuscula Entomologica, supplementum 24, p. 201–408.

MACROFOSSIL REPORT: MFRPT 94-109

Sample No.: JJO-05-07-89-P9
Lab No.: ES-95-0289
Locality: Revenue Creek placer mine, Y.T., downstream section Deep excavation through muck and valley gravel. Gravel deposition nonglacial but some erratics found at bottom of valley on bedrock.
Latitude: 62°20.22′ N **Longitude:** 137°16.35′ W **Elevation:** 630 m
Collected by: Lionel Jackson
Submitted by: Lionel Jackson
Stratigraphic unit: Fluvial deposit with angular to subrounded rusty gravel containing lenses of peaty organics and pieces of wood.
Material: Peaty lens in angular rusty gravel 1.7 m below surface.
Other: ^{14}C ages of >38 000 yrs. BP (GSC-4963) and >40 000 yrs. BP (GSC-4935) from spruce logs near the top of the section.

Key: + = taxon present, ++ = taxon common, +++ = taxon abundant

ANIMAL MACROFOSSILS:

ARTHROPODA		
INSECTA		
COLEOPTERA ...."beetles"	+	larval head capsules, articulated legs, mandibles, elytral fragments
Carabidae ...."ground beetles"		
Pterostichus(Cryobius)brevicornis Kby.	+	pronotum
Hydraenidae ...."minute moss beetles"		
Ochthebius sp.	+	elytron
Staphylinidae ....."rove beetles"		
Acidota sp.	+	pronotum
Aleocharinae	+	elytron
Leiodidae ...."round fungus beetles"		
Agathidium? sp.	+	pronotum
Ptiliidae ...."feather-winged beetles"		
Acrotrichus sp.	+	articulated: head, pronotum, elytra
Scarabaeidae ......"scarab beetles"		
Aegialia sp.	+	pronotum
Byrrhidae ...."pill beetles"		
Simplocaria spp.	+	pronota, head
Curculionidae ....."weevils"	+	elytral fragment, prothorax
Lepidophorus lineaticollis Kirby	+	prothorax, mesosternum, mesothorax
DIPTERA ...."flies"	+	pupae fragments, various types
Chironomidae ......"midges"	+	larval head capsules
HYMENOPTERA ...."wasps and ants"		
Ichneumonoidea ...."ichneumons and braconids"		
Ichneumonidae	+	head
Calcidoidea	+	head
ARACHNIDA		
Oribatei/Acari........."mites"	++	
Other:		
Fecal pellets	+	fragments, probably not mammalian
Net-like object	+	fragments

PLANT MACROFOSSILS:

Fungi:		
Fungal sclerotia	+++	
Fungal rhizome	+	
Bryophytes ...."mosses"		
Sphagnum sp.	+	fragments
Vascular plants:		
Pinaceae ...."pine family"	+	cone scale, seed fragment
Picea sp.	++	needles: fragments, some charred
Cyperaceae ...."sedge family"		
Carex canescens L.	+	seeds
Carex? sp.	+	seed
Salicaceae ...."willow family"		
Salix sp.	+	capsules, wood fragments
Betulaceae ...."birch family"	+	seeds
Alnus incana (L.)Moench.	+	seeds
Alnus sp.	+	seeds, bract
Betula aboreal type	+	seeds, bract fragments
Betula spp.	+++	seeds, bracts
Caryophyllaceae ..."pink family"	+	seed

Cruciferae ...."mustard family"	+	seed
Rosaceae ...."rose family"		
Potentilla sp.	+	seed
Rubus idaeus L.	+	seeds
Ericaceae ...."heath family"		
Empetrum nigrum L.	+	seeds
Unidentifiable plant taxa	+	seed capsules, seed
Other:		
Wood	+	fragments, mostly without bark, bud scars
Net-veined leaves	+	fragments

COMMENTS

The organic content in this sample is abundant and consist of mainly wood fragments of various sizes and states of preservation, moss fragments including *Sphagnum*, and plant remains. As seen in many of the downstream section samples, sample P9 contains a few pieces of charred wood and charred spruce needles, evidence that a fire has occurred at or near the site.

Insect fossils in sample P9 are well preserved and contain a variety of taxa including the rarely seen feather-winged beetle, Ptiliidae. This insect is the smallest known beetle measuring 1 mm in length. Sample P9 contains articulated insect fossil fragments of the genus *Acrotrichus*, which can be found living in or near swamps and bogs. Another rarely seen fossil insect, the round fungus beetle (Leiodidae), also appears in this sample. This beetle lives in fungi, under bark and in decaying wood.

Sample P9 also contains insect fossil fragments of shoreline type insects including *Simplocaria*, a pill beetle and *Aegialia*, a scarab beetle, both which live in taiga (tundra and/or forest) habitats near shorelines of wet environments. As seen in many other Revenue Creek samples, this sample also contains fragments of the weevil *Lepidophorus lineaticollis*. This insect lives among willows and alders along sandy shorelines or rivers, at dry sites within forests and at dry tundra sites. This sample also contains insect fossil head capsules of the aquatic larval midges, Chironomidae.

The plant macrofossil assemblage in sample P9 is very similar to sample P8 except birch dominates most of the assemblage in sample P9 as opposed to sample P8 which contains predominantly spruce macrofossils. Samples P8 and P9 are the only samples in the downstream section to contain birch including abundant arboreal trees. Spruce (*Picea*) needles are the next abundant macrofossil in sample P9. This sample also contains fungal sclerotia, alder (*Alnus*), raspberry(*Rubus ideaus*), and crowberry (*Empetrum nigrum*) seeds. Raspberries are shrubs that live in the margins of trees and crowberry plants prefer to grows in acidic soils. Similar to sample P8, only a few plant macrofossils of *Carex* appear in this sample. Sample P9, however, does contain macrofossil seeds of *Carex canescens*, a sedge common in bogs and swamps.

The combined plant and insect fossil evidence suggests two types of environments. The predominant environment is a dense forest of spruce, birch, and alder. Shrubs of willow and raspberries can be found growing along the margins of the forest and crowberry is growing on the drier acidic soils. Fossil evidence also indicates the presence of a wet environment with mosses, sedge, and rush plants growing along the shoreline. Insect fossil evidence further supports this in containing many shoreline-type beetles. All of the fossils in this sample represent taxa that can be found living today in Yukon Territory.

APPENDIX E

WOOD IDENTIFICATIONS FROM REVENUE CREEK

Hélène Jetté

WOOD IDENTIFICATION REPORT NO. 95.004

Date: February 02, 1995
Locality: Revenue Creek placer mine, Y.T.
Latitude: 62°20.22′ N **Longitude:** 137°16.35′ W
NTS: 115-I
Submitted by: Lionel Jackson
Field No.: JJO-5789 W1, 2, 3, 7, 7a, 8, 9, 14
Paleoecology Laboratory Number: PL-94.177 W1,2,3,7,7a,8,9,14
Description of sample: Wood samples from a deep excavation through muck and valley gravels.
Identification: Samples W1, W7a, W8, W9 identified as *Picea* sp. (spruce). Sample W14 identified as *Salix* sp. (willow).

Samples W2, W3, W7 too badly preserved, almost disintegrated, impossible to prepare microscope slides for identification.

Wood samples *(Picea)* at the top of the section have previously been dated at >38 000 BP (GSC-4963) and >40 000 BP (GSC-4935).

At the exception of sample W9, the wood samples come from fluvial deposits that predate the McConnell (late Wisconsin) Glaciation.

erlie the floors and margins
slope) into colluvial
nd ice wedges and are
y represent several
m in mid-valley locations

Recommended citation:
Jackson, L.E., Jr.
1997: Surficial geology, Victoria Creek, Yukon Territory;
Geological Survey of Canada, Map 1876A, scale 1:100 000

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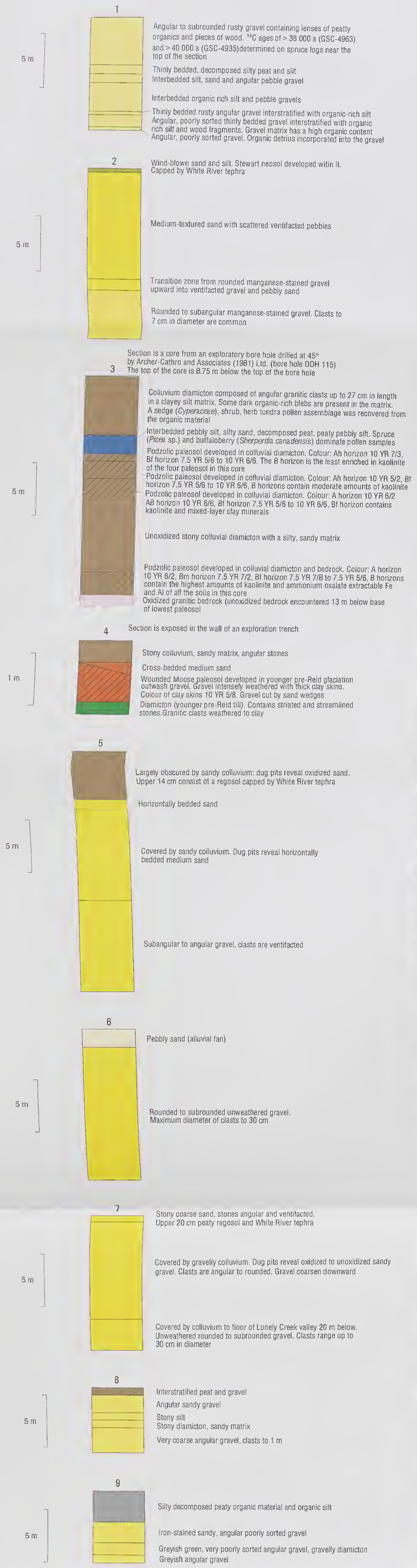


LEGEND FOR STRATIGRAPHIC SECTIONS

QUATERNARY

POSTGLACIAL

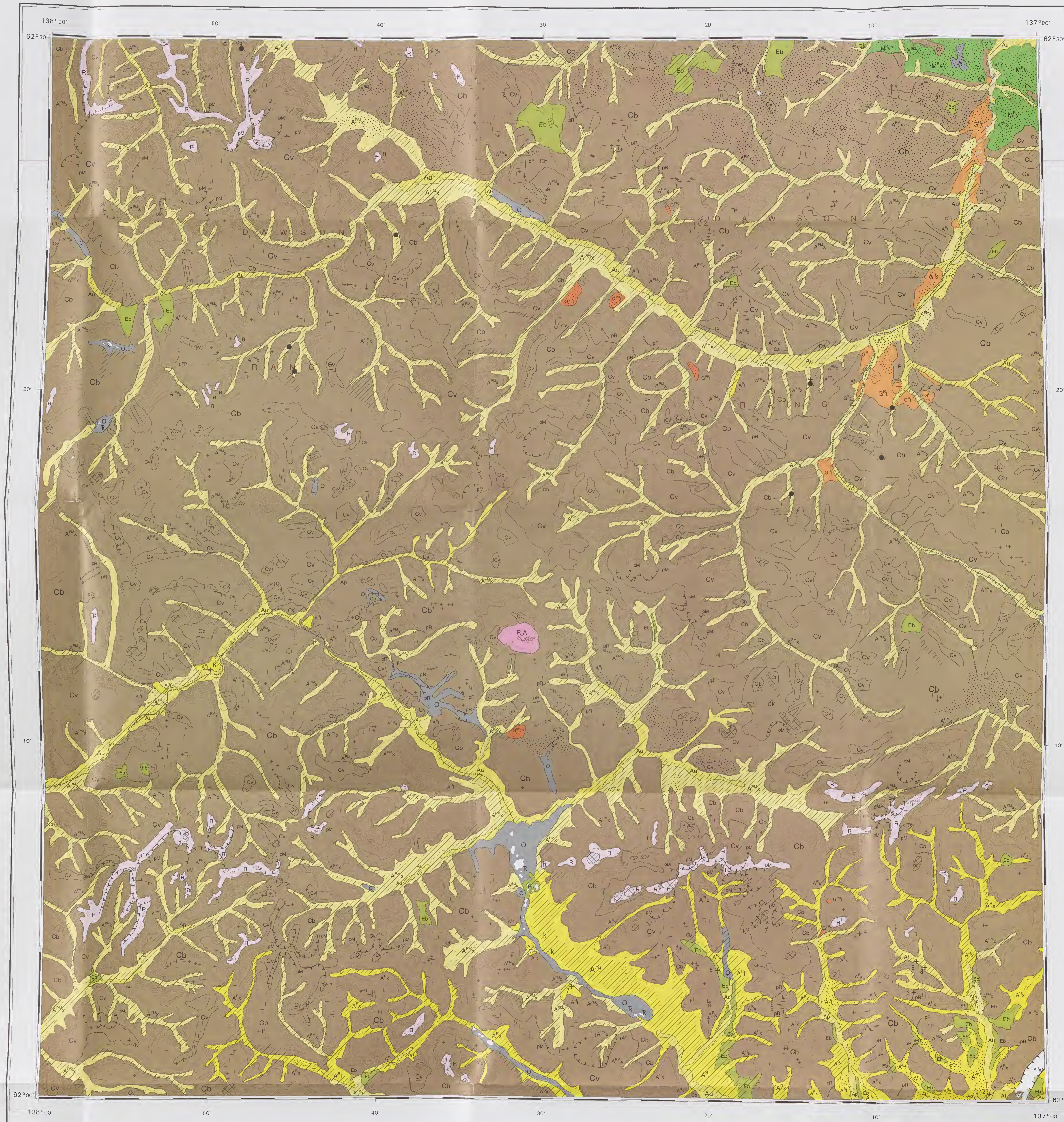
- *Peat and other organic sediments*
- *Eolian sediments and White River tephra*
- *Alluvial (Holocene) sands and gravels*

MIDDLE TO LATE PLEISTOCENE

- *Colluvium*
- *Alluvial sediments of unknown age*
- *Stream deposited sediments (pre-McConnell Glaciation) of nonglacial origin (includes terrace gravels along Klaza River possibly deposited by outlet waters from a lake dammed by a glacial margin along the southern margin of Dawson range during Reid Glaciation)*

EARLY TO MIDDLE PLEISTOCENE

- *Alluvial sediments graded to the glacial margin, Reid Glaciation*
- *Lacustrine sediments from uncorrelated middle or late Pleistocene interglacials*
- *Paleosol developed between the younger pre-Reid glaciation and Reid glaciation*
- *Till, younger pre-Reid glaciation*
- *Glaciofluvial sediments, younger pre-Reid glaciation*
- *Paleozoic and Mesozoic bedrock*



LEGEND

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This legend is common to maps 1876A-1879A

CENOZOIC

QUATERNARY

HOLOCENE – POST-McCONNELL GLACIATION

ORGANIC DEPOSITS: peat and muck formed predominently by the accumulation of vegetative material in bogs, fens, and swamps situated on valley bottoms and blanket bog on hillsides (see SYMBOLS below). Permafrost is commonly encountered within 1 m of the surface. Open system pingos are common in blanket bog and thermokarst collapse and palsa growth are common in bogs, fens, and swamps

O	*Bog, fen, and swamp deposits: undivided; thickness < 1 m to 10 m*

ALLUVIAL DEPOSITS: gravel to silt size sediments deposited by streams

Ap	*Floodplain sediments: gravel, cobble to pebble; massive to thick bedded capped by sand and silt; flat lying; includes lacustrine and organic deposits in abandoned channels and backswamp areas subject to periodic inundation and reworking by floods; thickness 1 to 5 m*
At	*Alluvial terrace sediments: gravel, cobble to pebble with a sandy matrix; massive to thick bedded; capped by sands and silts; sediments are of flood plain origin now isolated from flooding by stream incisions; thickness 1 m to 10 m or more*
Af	*Alluvial fan sediments: gravel, sand, silt, and diamicton, poorly sorted; thick bedded to massive; sediments form fan-shaped landforms at the confluence of tributary streams with lower gradient trunk streams; subject to flooding accompanied by sudden stream migration and inundation by debris flows on fans with gradients in excess of 4%; thickness up to 10 m or more*
Au	*Alluvial sediments, undivided: sediments forming floodplains, fans, and terraces as above that cannot be subdivided at this map scale*

PLEISTOCENE AND HOLOCENE (UNDIVIDED)

EOLIAN DEPOSITS: well sorted medium sand to coarse silt transported and deposited by wind action during the early postglacial and McConnell Glaciation. Thin deposits of very fine sand and coarse silt < 1 m thick are distributed discontinuously throughout low lying areas (see SYMBOLS below)

Eb	*Eolian sands: sand, well sorted; massive; forms crescent-shape and linear dunes and featureless or gently undulating inter-dune eolian plains; thickness 1 to 5 m*

COLLUVIAL DEPOSITS: stony diamicton resulting from the physical and chemical breakdown of bedrock and reworking and transportation by creep, solifluction, debris flow, snow avalanching, and rockfall. It also includes diamicton created by landsliding. Colluvial deposits may contain reworked glacial sediments within the limits of ice cover during the Reid and McConnell glaciations. Colluvial deposits beyond the limits of the McConnell Glaciation ice cover are likely the product of continuous formation and reworking over a significant part of the Pleistocene

Cb	*Colluvial blanket sediments: diamicton, stony with a sandy matrix; massive; surface conforms to underlying bedrock or buried glacial deposits; thickness > 1 m to 50 m or more in large landslides*
Cv	*Colluvial veneer sediments: diamicton, stony with a sandy matrix; massive; thickness < 1 m to discontinuous over bedrock*
Ca	*Colluvial apron sediments: diamicton, bouldery diamicton and bouldery sandy gravel, poorly sorted; massive; sediments form a wedge-like slope-toe complex of small steep debris flow and avalanche-dominated fans and solifluction deposits; thickness is < 1 m at up and down slope limit to up to 5 m or more in the thickest part of the apron*
bCa	*Rockfall sediments: boulders, angular; massive; deposits form as rockfall accumulations along the bases of steep bedrock slopes; thickness ranges from < 1 m at margins to up to 10 m*

LATE PLEISTOCENE (WISCONSINAN) – McCONNELL GLACIATION

GLACIOLACUSTRINE DEPOSITS: well stratified sand, silt, clay, deposited in lakes ponded by glacial ice. Glaciolacustrine sediments may have regular surfaces or have ridged, hummocky, or pitted surfaces caused by meltout of former supporting glacial ice . Glaciolacustrine silt and clay commonly contain extensive segregated ground ice. Consequently, they are widely affected by thermokarst collapse and retrogressive thaw landsliding along rivers

Lp, Lb, Lv, Lx — *Glaciolacustrine plain; Glaciolacustrine blanket; Glaciolacustrine veneer; Ice-contact glaciolacustrine complex* [descriptions illegible at page scale]

GLACIOFLUVIAL DEPOSITS

Gp, Gt, Gd, Gx, Gu — *Glaciofluvial plain sediments; Glaciofluvial terrace sediments; Glaciofluvial delta sediments; Glaciofluvial ice stagnation complex sediments; Discontinuous glaciofluvial sediments* [descriptions illegible at page scale]

MORAINAL DEPOSITS (TILL)

Mb, Mv — *Till blanket; Till veneer* [descriptions illegible at page scale]

MIDDLE PLEISTOCENE – PRE-McCONNELL GLACIATION (UNDIVIDED)

ALLUVIAL DEPOSITS

$A^{PM}f$, $A^{PM}x$ — *Alluvial fans; Alluvial complex sediments* [descriptions illegible at page scale]

MIDDLE PLEISTOCENE – REID GLACIATION

ALLUVIAL DEPOSITS

$A^{R}t$, $A^{R}f$, $A^{R}x$ — *Alluvial terrace sediments; Alluvial fans; Alluvial complex sediments* [descriptions illegible at page scale]

GLACIOLACUSTRINE DEPOSITS

$L^{R}p$ — *Glaciolacustrine plain* [description illegible at page scale]

GLACIOFLUVIAL DEPOSITS

$G^{R}p$, $G^{R}t$, $G^{R}d$, $G^{R}x$ — *Glaciofluvial plain sediments; Glaciofluvial terrace sediments; Glaciofluvial delta sediments; Glaciofluvial ice stagnation complex sediments* [descriptions illegible at page scale]

MORAINAL DEPOSITS (TILL)

$M^{R}b$, $M^{R}v$ — *Till blanket; Till veneer* [descriptions illegible at page scale]

EARLY PLEISTOCENE – YOUNGER PRE-REID GLACIATION

GLACIOFLUVIAL DEPOSITS

$G^{PR}p$, $G^{PR}t$ — *Glaciofluvial plain sediments; Glaciofluvial terrace sediments* [descriptions illegible at page scale]

MORAINAL DEPOSITS (TILL)

$M^{PR}v$ — *Till veneer* [description illegible at page scale]

EARLY PLEISTOCENE

VOLCANIC ROCK and INTERSTRATIFIED SEDIMENTS

V — *Pleistocene volcanics (undivided)* [description illegible at page scale]

PALEOZOIC AND MESOZOIC

R — *PRE-QUATERNARY BEDROCK* [description illegible at page scale]

R-A — *AVALANCHE MODIFIED PRE-QUATERNARY BEDROCK* [description illegible at page scale]

SYMBOLS

[symbol list illegible at page scale]

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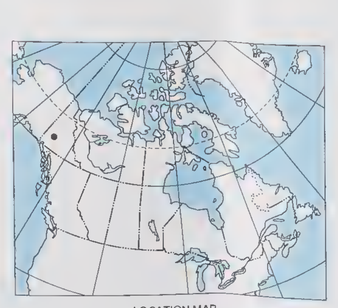

LOCATION MAP

MAP 1876A

SURFICIAL GEOLOGY

VICTORIA CREEK

YUKON TERRITORY

Scale 1:100 000 - Échelle 1/100 000

Surficial geology by L.E. Jackson Jr. 1988-1992, Geological Survey of Canada

Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

Universal Transverse Mercator Projection / Projection transverse de Mercator

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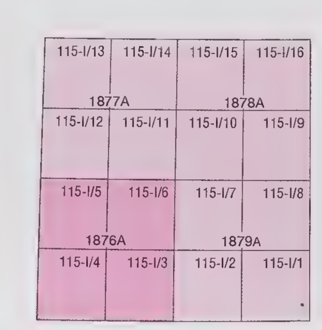
Elevations in feet above mean sea level



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE AND INDEX TO ADJOINING GEOLOGICAL SURVEY OF CANADA MAPS

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1997: Surficial geology, Victoria Creek, Yukon Territory; Geological Survey of Canada, Map 1876A, scale 1:100 000

Tempelman-Kluit, D.J.
1979; Geology of the Laberge (105E) and Carmacks (115-I) Yukon, Geological Survey of Canada, Open File 1101

Recommended citation:
Jackson, L.E., Jr.
1997: Surficial geology, Victoria Rock, Yukon Territory; Geological Survey of Canada, Map 1877A, scale 1:100 000

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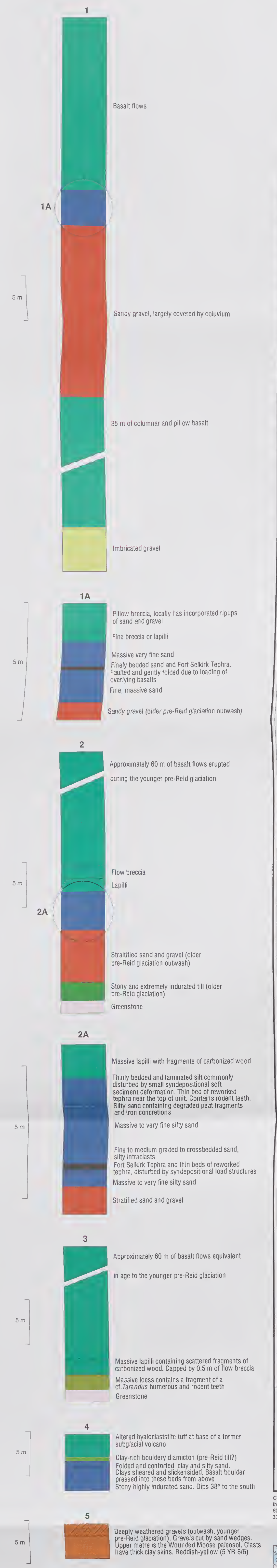
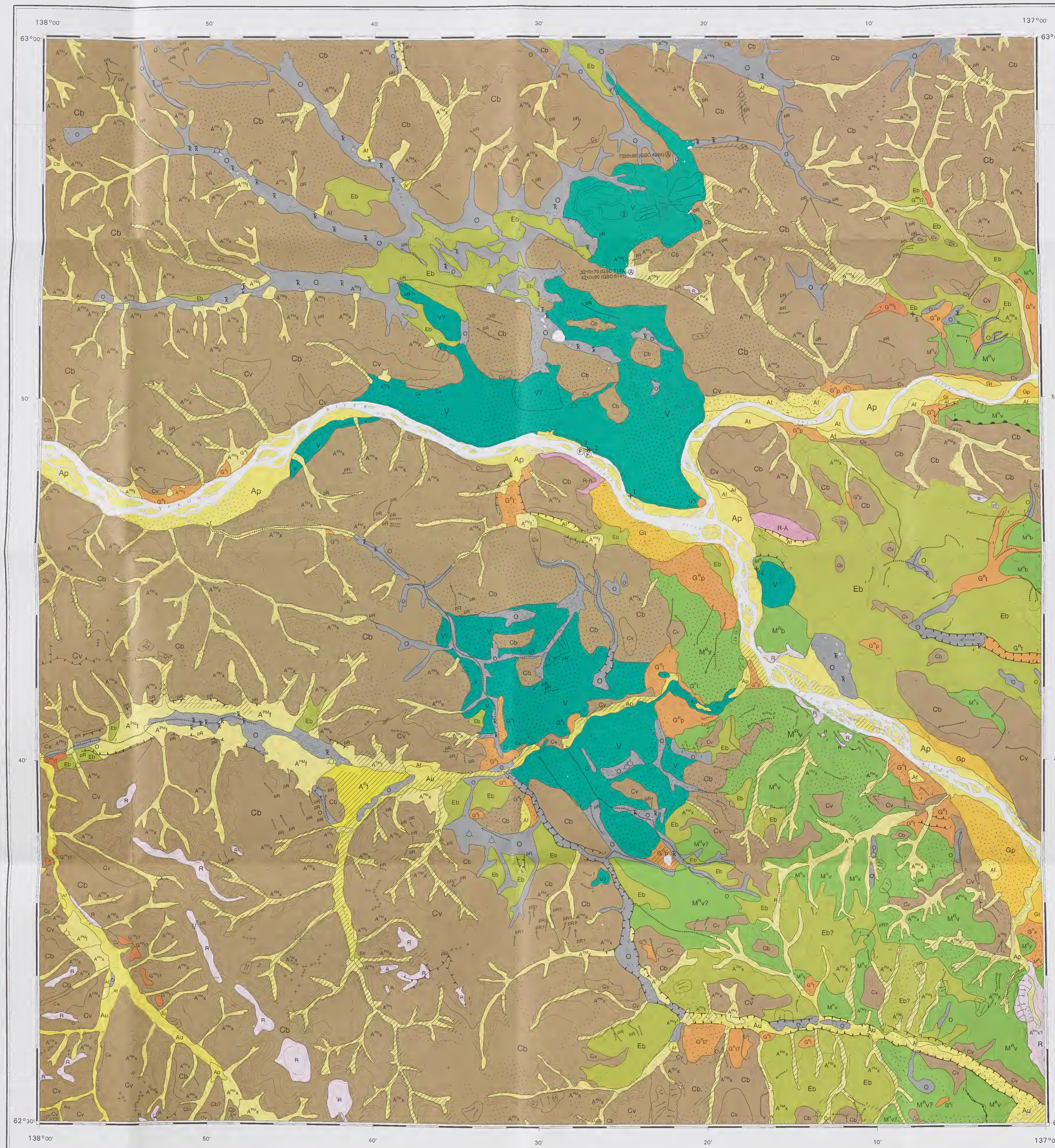


LEGEND FOR STRATIGRAPHIC SECTIONS

QUATERNARY

EARLY TO MIDDLE PLEISTOCENE

- *Paleosol developed between the younger pre-Reid glaciation and Reid Glaciation*
- *Till, younger pre-Reid glaciation*
- *Glaciofluvial sediments, younger pre-Reid glaciation*
- *Nonglacial predominantly lacustrine sediments deposited during an interglacial between pre-Reid glaciations*
- *Eolian sands and silts deposited during an intergacial between pre-Reid glaciations*
- *Till, older pre-Reid glaciation*
- *Glaciofluvial sediments, older pre-Reid glaciation*
- *Basalt, volcanic ejecta, and hyaloclastite of the Selkirk volcanics*
- *Possible pre-glacial fluvial sediments*
- *Paleozoic and Mesozoic bedrock*



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Published 1997

LOCATION MAP

MAP 1877A
SURFICIAL GEOLOGY

VICTORIA ROCK

YUKON TERRITORY

Scale 1:100 000 - Échelle 1/100 000

Kilometres 2 0 2 4 6 8 Kilomètres

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Surficial geology by L.E. Jackson Jr. 1988-1992, Geological Survey of Canada

Digital cartography by J.D. Narraway, Geoscience Information Division

Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

Base map assembled and modified by the Geoscience Information Division from maps 115-I/12 (1970), 115-I/ 11,13,14 (1961) published at the scale of 1:50 000 by the Surveys and Mapping Branch

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Mean magnetic declination 1997, 28°16′ E, decreasing 11.9′ annually. Readings vary from 28°11′ E in the SE corner to 28°21′ E in the NW corner of the map

Elevations in feet above mean sea level

NATIONAL TOPOGRAPHIC SYSTEM REFERENCE AND INDEX TO ADJOINING GEOLOGICAL SURVEY OF CANADA MAPS

LEGEND

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CENOZOIC

QUATERNARY

HOLOCENE – POST-McCONNELL GLACIATION

ORGANIC DEPOSITS: peat and muck formed predominantly by the accumulation of vegetative material in bogs, fens, and swamps situated on valley bottoms and blanket bog on hillsides (see SYMBOLS below). Permafrost is commonly encountered within 1 m of the surface. Open system pingos are common in blanket bog and thermokarst collapse and palsa growth are common in bogs, fens, and swamps

O — *Bog, fen, and swamp deposits: undivided; thickness < 1 m to 10 m*

ALLUVIAL DEPOSITS: gravel to silt size sediments deposited by streams

Ap — *Floodplain sediments: gravel, cobble to pebble; massive to thick bedded capped by sand and silt; flat lying; includes lacustrine and organic deposits in abandoned channels and backswamp areas subject to periodic inundation and reworking by floods; thickness 1 to 5 m*

At — *Alluvial terrace sediments: gravel, cobble to pebble with a sandy matrix; massive to thick bedded; capped by sands and silts; sediments of a flood plain origin now isolated from flooding by stream incision; thickness 1 m to 10 m or more*

Af — *Alluvial fan sediments: gravel, sand, silt, and diamicton, poorly sorted; thick bedded to massive; sediments form fan-shaped landforms at the confluence of tributary streams with lower gradient trunk streams; subject to flooding accompanied by sudden stream migration and inundation by debris flows on fans with gradients in excess of 4%; thickness up to 10 m or more*

Au — *Alluvial sediments, undivided: sediments forming floodplains, fans, and terraces as above that cannot be subdivided at this map scale*

PLEISTOCENE AND HOLOCENE (UNDIVIDED)

EOLIAN DEPOSITS: well sorted medium sand to coarse silt transported and deposited by wind action during the early postglacial and McConnell Glaciation. Thin deposits of very fine sand and coarse silt < 1 m thick are distributed discontinuously throughout low lying areas (see SYMBOLS below)

Eb — *Eolian sands: sand, well sorted; massive; forms crescent-shape and linear dunes and featureless or gently undulating inter-dune eolian plains; thickness 1 to 5 m*

COLLUVIAL DEPOSITS: stony diamicton resulting from the physical and chemical breakdown of bedrock and reworking and transportation by creep, solifluction, debris flow, snow avalanching, and rockfall. It also includes diamicton created by landsliding. Colluvial deposits may contain reworked glacial sediments within the limits of ice cover during the Reid and McConnell glaciations. Colluvial deposits beyond the limits of the McConnell Glaciation ice cover are likely the product of continuous formation and reworking over a significant part of the Pleistocene

Cb — *Colluvial blanket sediments: diamicton, stony with a sandy matrix; massive; surface conforms to underlying bedrock or buried glacial deposits; thickness > 1 m to 50 m or more in large landslides*

Cv — *Colluvial veneer sediments: diamicton, stony with a sandy matrix; massive; thickness < 1 m to discontinuous over bedrock*

Ca — *Colluvial apron sediments: diamicton, bouldery diamicton and bouldery sandy gravel, poorly sorted; massive; sediments form a wedge-like slope-toe complex of small steep debris flow and avalanche-dominated fans and solifluction deposits; thickness 0 < 1 m at up and down slope limit to up to 5 m or more in the thickest part of the apron*

bCa — *Rockfall sediments: boulders, angular; massive; deposits form as rockfall accumulations along the bases of steep bedrock slopes; thickness ranges from < 1 m at margins to up to 10 m*

LATE PLEISTOCENE (WISCONSINAN) – McCONNELL GLACIATION

GLACIOLACUSTRINE DEPOSITS: well stratified sand, silt, clay, deposited in lakes ponded by glacial ice. Glaciolacustrine sediments may have regular surfaces or have ridged, hummocky, or pitted surfaces caused by meltout of former supporting glacial ice. Glaciolacustrine sediments commonly contain extensive segregated ground ice. Consequently, they are widely affected by thermokarst collapse and retrogressive thaw landsliding along rivers

Lp — *Glaciolacustrine plain: sand, silt, and clay with minor dropstones; thinly bedded to laminated; thickness > 5 m*

Lb — *Glaciolacustrine blanket: silt and clay with minor sand; thinly bedded to laminated; deposit conforms to underlying topography; thickness 1 m to 5 m*

Lv — *Glaciolacustrine veneer: silt and clay with minor sand; thinly bedded to laminated; deposit conforms to underlying topography; thickness < 1 m to discontinuous*

Lx — *Ice-contact glaciolacustrine complex: sand, silt, and clay laminated to medium bedded with up to 10 percent lenticular beds of gravel and diamicton and dropstones; surface is hummocky, pitted, and ridged; thickness > 5 m*

GLACIOFLUVIAL DEPOSITS: sands, gravels and minor silts > 1 m thick deposited by streams flowing away from, or in contact with glacial ice including deltas graded to former glacial lakes. Sorting ranges from good to poor and stratification from thin bedded to massive. Sediments commonly display evidence of syndepositional collapse due to meltout of buried or supporting ice

Gp — *Glaciofluvial plain sediments: pebble to cobble gravel; massive to thick bedded, capped by sand and silt; planar surface; thickness 1 to > 10 m*

Gt — *Glaciofluvial terrace sediments: pebble to cobble gravel; massive to thick bedded; incised into flights of terraces by glacial streams; thickness 1 to > 10 m*

Gd — *Glaciofluvial delta sediments: sand, gravel, and minor silt and clay, moderately to well sorted, texture becomes finer downward; massive to thick bedded; deposit has a planar surface and delta-form in plan view; thickness > 5 m*

Gx — *Glaciofluvial ice stagnation complex sediments: gravel, sand, diamicton, poorly to moderately sorted, and minor silt and clay; bedding thick to massive and commonly folded and faulted from syndepositional ice meltout; surface consists of hummocks, kettles, esker and crevasse-fill ridges with minor elements of units Gp, Gd, and Gt*

Gu — *Discontinuous glaciofluvial sediments: gravel and sand including elements of units Gp and Gx, discontinuously distributed in areas of units Mb and Mv*

MORAINAL DEPOSITS (TILL): glacial diamicton, mainly till, generally consisting of a matrix ranging from sand to clay that supports clasts ranging from boulders to pebbles in size; deposited either directly from glacial ice or by gravity flow from glacial ice

Mb — *Till blanket: diamicton, stony with a silty, sandy matrix; massive to crudely stratified; surface conforms to the underlying topography; thickness 1 to 5 m*

Mv — *Till veneer: diamicton, stony with a silty, sandy matrix; massive to crudely stratified; may contain extensive areas of thin (< 1 m) to patchy colluvium over bedrock*

MIDDLE PLEISTOCENE – PRE-McCONNELL GLACIATION (UNDIVIDED)

ALLUVIAL DEPOSITS: gravel and sand deposited by streams that were not fed by glacial meltwaters. Sediments may represent several cycles of alluviation and erosion. Sediments are not presently correlative to past glaciations but presumably predate McConnell Glaciation due to the presence of McConnell age loess overlying them. Basal gravels within these sediments commonly contain placer gold in basins draining Cretaceous granodiorite and andesite

$A^{PM}f$ — *Alluvial fans: single fans or aprons of coalesced fans formed of gravel and sand, poorly to moderately sorted, thick bedded. Sediments disturbed by cryoturbation and clasts commonly wind sculpted. Thickness up to 10 m or more*

$A^{PM}x$ — *Alluvial complex sediments: gravel and sand, poorly to moderately sorted; thin to thick bedded, interbedded with colluvial diamicton, reworked loess, peat, and woody detritus; sediments underlie the floors and margins of narrow upland valleys and grade laterally (upslope) into colluvial blankets. They contain segregated ice lenses and ice wedges and are normally capped by blanket bog; sediments may represent several depositional cycles; thickness may exceed 10 m in mid-valley locations*

MIDDLE PLEISTOCENE – REID GLACIATION

ALLUVIAL DEPOSITS: complexes of nonglacial and fan sands and gravels deposited by streams that flowed from ice-free areas toward Reid Glaciation ice margins. These sands and gravels locally overlie older interglacial gravels that contain placer gold

$A^{R}t$ — *Alluvial terrace sediments: gravelly micaceous sand and gravel, moderately sorted, clasts angular to subangular; bedding is thin to massive and lenticular; gravel clasts are commonly frost shattered and wind sculpted; sediments have been incised into flights of terraces. Sediments are commonly cut by ice wedge pseudomorphs over their upper 2 m (includes terrace gravels along Klaza River possibly deposited by outlet waters from a lake dammed by a glacial margin during Reid Glaciation). Thickness 1 to 15 m*

$A^{R}f$ — *Alluvial fans: single fans or aprons of coalesced fans formed of gravel and sand, poorly to moderately sorted, thick bedded. Sediments disturbed by cryoturbation and clasts commonly wind sculpted. Thickness up to 10 m or more*

$A^{R}x$ — *Alluvial complex sediments: gravel and sand, poorly to moderately sorted; thin to thick bedded, interstratified with colluvial diamicton, reworked loess, peat, and woody detritus; sediments underlie the floors and margins of narrow upland valleys and grade laterally (upslope) into colluvial blankets. They contain segregated ice lenses and ice wedges and are normally capped by blanket bog; sediments may represent several depositional cycles; thicknesses may exceed 10 m in mid-valley locations*

GLACIOLACUSTRINE DEPOSITS: well stratified sand, silt, clay, and minor gravel and diamicton deposited in lakes ponded by glacial ice. Glaciolacustrine silts and clays commonly contain segregated ground ice and are affected by contemporary thermokarst collapse

$L^{R}p$ — *Glaciolacustrine plain: sand, silt, and clay, with minor dropstones; thinly bedded to laminated; thickness 1 to > 5 m*

GLACIOFLUVIAL DEPOSITS: gravel and sand deposited by streams flowing away from, or in contact with glacial ice

$G^{R}p$ — *Glaciofluvial plain sediments: gravel and sand, moderately to well sorted; thick bedded to massive; planar surface; thickness 1 to 10 m or more*

$G^{R}t$ — *Glaciofluvial terrace sediments: pebble to cobble gravel; massive to thick bedded; incised into flights of terraces by glacial streams; thickness 1 to > 10 m*

$G^{R}d$ — *Glaciofluvial delta sediments: sand, gravel and minor silt and clay, moderately to well sorted and becomes finer downward; massive to thick bedded; planar surface, deposit is delta form in plan view; thickness > 5 m*

$G^{R}x$ — *Glaciofluvial ice stagnation complex sediments: gravel, sand, diamicton, poorly to moderately sorted, and minor silt and clay; bedding thick to massive and commonly folded and faulted from syndepositional ice meltout; surface consists of hummocks, kettles, esker and crevasse-fill ridges with minor elements of units $G^{R}p$, $G^{R}d$, and $G^{R}t$*

MORAINAL DEPOSITS (TILL): glacial diamicton, mainly till, generally consisting of a matrix ranging from sand to clay that supports clasts ranging from boulders to pebbles in size; deposited either directly from glacial ice or by gravity flow from glacial ice

$M^{R}b$ — *Till blanket: diamicton, stony, silty sandy matrix; massive; conforms to underlying topography; thickness 1 to 5 m*

$M^{R}v$ — *Till veneer: diamicton, stony, silty sandy matrix; massive; discontinuous and may contain extensive areas of thin (< 1 m) and patchy colluvium over bedrock*

EARLY PLEISTOCENE – YOUNGER PRE-REID GLACIATION

GLACIOFLUVIAL DEPOSITS: gravel and sand deposited by streams flowing away from glacial ice in meltwater channels and outwash planes. Thick bedded to massive; clasts, except for quartz, quartzite, and chert are disaggregated or weathered to clay over the upper 2 m of the sediments where they underlie the surface; clasts near the surface of the unit are intensely wind sculpted and this interval is cut by ice wedge pseudomorphs and sand wedges; thickness 1 m to > 5 m

$G^{PR}p$ — *Glaciofluvial plain sediments: gravel and sand, deeply weathered; forms an unincised plain*

$G^{PR}t$ — *Glaciofluvial terrace sediments: gravel and sand, deeply weathered; incised into flights of terraces*

MORAINAL DEPOSITS (TILL): glacial diamicton, mainly till, generally consisting of a matrix ranging from sand to clay that supports clasts ranging from boulders to pebbles in size; deposited either directly from glacial ice or by gravity flow from glacial ice

$M^{PR}v$ — *Till veneer: patchy, deeply weathered diamicton. Matrix sandy silty clay. Formerly feldspar-rich stones are weathered to clay*

EARLY PLEISTOCENE

VOLCANIC ROCK and INTERSTRATIFIED SEDIMENTS

V — *Pleistocene volcanics (undivided): basalt, breccia, volcanic ejecta and hyaloclastite of the Selkirk volcanics erupted during the early and late Pleistocene or early Holocene epochs in the Fort Selkirk area. Cumulative basalt flow thicknesses exceed 100 m where they have filled valleys. Deposits of the two known pre-Reid glaciations and at least one nonglacial period are locally interstratified with the volcanics and are exposed only in sections*

PALEOZOIC AND MESOZOIC

R — *PRE-QUATERNARY BEDROCK: basalt, andesite, greenstone, schist, gneiss, greywacke, granodiorite and monzonite: includes areas of thin colluvial cover, blockfields, sorted stone polygons in alpine areas*

R-A — *AVALANCHE MODIFIED PRE-QUATERNARY BEDROCK: bedrock areas subject to rapid mass wasting processes (rockfall and snow avalanches)*

SYMBOLS

Note: pR *- pre-Reid glaciations,* r *- Reid Glaciation,* pM *- pre-McConnell Glaciation, (no designator, assume McConnell Glaciation)*

- *Geological boundary*
- *Blanket bog covering generally less than 1 m thick*
- *Discontinuous eolian sands or silts, thickness locally up to 2 m*
- *Open system pingo, collapsed open system pingo*
- *Thermokarst collapse activity*
- *Landslide, arrow(s) indicate direction of movement*
- *Cirque: degraded cirque active prior to McConnell Glaciation*
- *Arête: degraded arête active prior to McConnell Glaciation*
- *Streamlined glacial bedforms: ice flow direction known, unknown*
- *Meltwater channel; large, small ice-walled channel, arrow indicates flow direction*
- *Esker: flow direction defined, unknown*
- *End moraine*
- *Recessional moraine*
- *Ice-contact face in stratified drift (teeth on ice side)*
- *Ice limit*
- *Cryoplanation terrace*
- *Tor*
- *Vertebrate fossil locality*
- *Stratigraphic section*
- *Radiocarbon date in years (GSC Lab No.)* .... 3210±70 (GSC 5413) (A)

REFERENCES

Extent of Selkirk volcanics from:

Frances, D. and Ludden, J.
1990; The mantle source for olivine nephelinite basanite and alkaline olivine basalt at Fort Selkirk, Yukon, Canada; Journal of Petrology, v.31, p. 371-400

Tempelman-Kluit, D.J.
1979; Geology of the Laberge (105E) and Carmacks (115-I) Yukon, Geological Survey of Canada, Open File 1101

Canada

Recommended citation:
Jackson, L.E., Jr.
1997: Surficial geology, Victoria Rock, Yukon Territory; Geological Survey of Canada, Map 1877A, scale 1:100 000

to moderately sorted;
micton, reworked
the floors and margins
e) into colluvial
e wedges and are
present several
in mid-valley locations

Vertebrate fossil locality . . . . Ⓕ

Stratigraphic section . . . . 2+

Recommended citation:
Jackson, L.E., Jr.
1997: Surficial geology, Granite Canyon, Yukon Territory; Geological Survey of Canada, Map 1878A, scale 1:100 000

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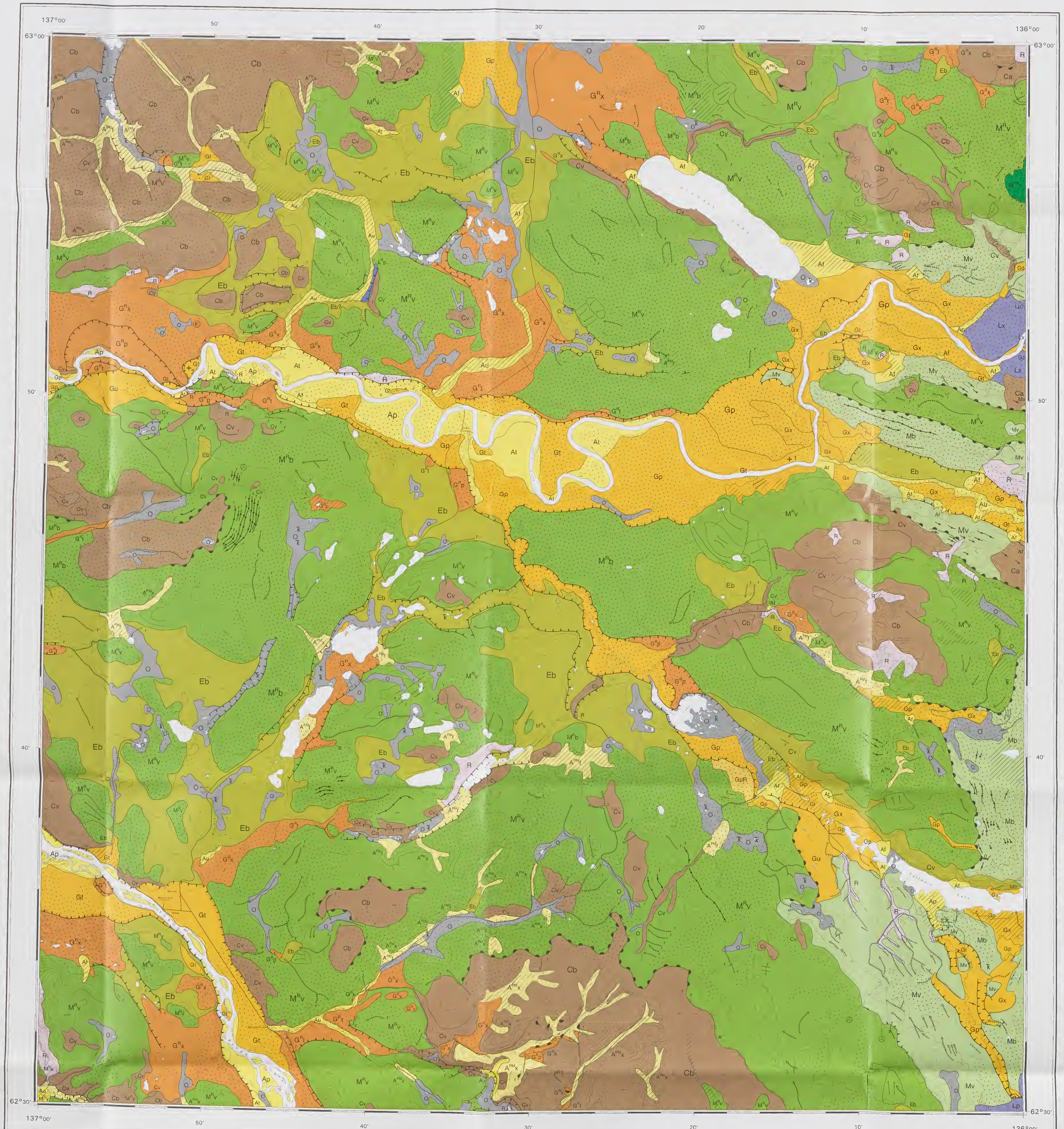

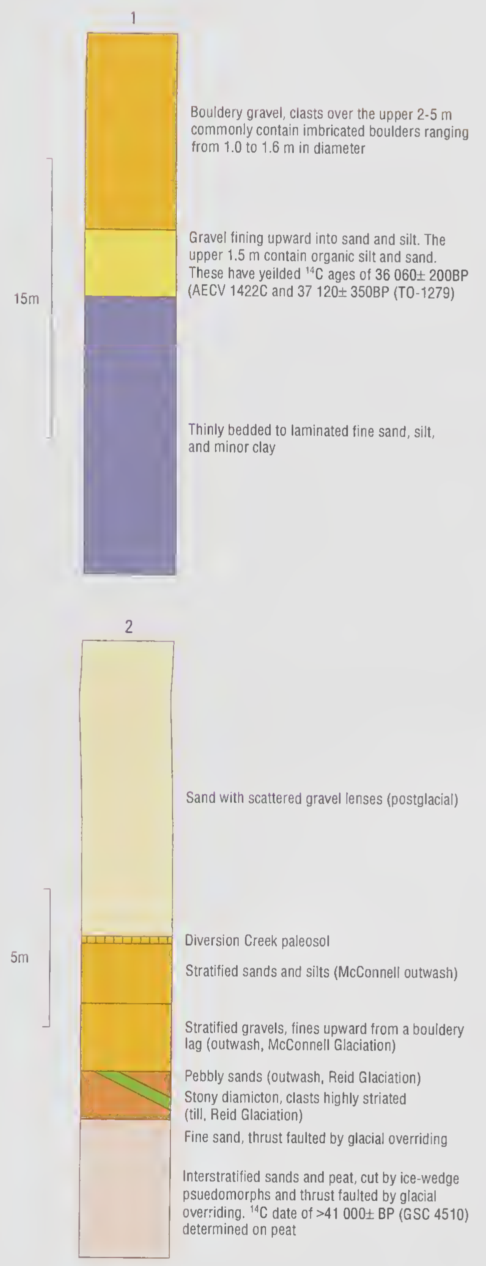

LEGEND FOR STRATIGRAPHIC SECTIONS

QUATERNARY

POSTGLACIAL

- Alluvial (Holocene) sands and gravels

MIDDLE TO LATE PLEISTOCENE

- Glaciofluvial sediments, McConnell Glaciation
- Paleosol developed between Reid and McConnell Glaciation
- Stream deposited sediments (pre-McConnell Glaciation) of nonglacial origin (includes terrace gravels along Klaza River possibly deposited by outlet waters from a lake dammed by a glacial margin along the southern margin of Dawson range during Reid Glaciation)

EARLY TO MIDDLE PLEISTOCENE

- Till, Reid Glaciation
- Glaciofluvial sediment, Reid Glaciation
- Glaciolacustrine sediments, Reid Glaciation
- Alluvial deposits, deposited between the younger pre-Reid glaciation and Reid glaciation

LEGEND

Coloured legend blocks indicate map units that appear on this map
This legend is common to maps 1876A-1879A

CENOZOIC

QUATERNARY

HOLOCENE – POST-McCONNELL GLACIATION

ORGANIC DEPOSITS: peat and muck formed predominently by the accumulation of vegetative material in bogs, fens, and swamps situated on valley bottoms and blanket bog on hillsides (see SYMBOLS below). Permafrost is commonly encountered within 1 m of the surface. Open system pingos are common in blanket bog and thermokarst collapse and palsa growth are common in bogs, fens, and swamps

O — *Bog, fen, and swamp deposits: undivided; thickness < 1 m to 10 m*

ALLUVIAL DEPOSITS: gravel to silt size sediments deposited by streams

Ap — *Floodplain sediments: gravel, cobble to pebble; massive to thick bedded capped by sand and silt; flat lying; includes lacustrine and organic deposits in abandoned channels and backswamp areas subject to periodic inundation and reworking by floods; thickness 1 to 5 m*

At — *Alluvial terrace sediments: gravel, cobble to pebble with a sandy matrix; massive to thick bedded; capped by sands and silts; sediments are of flood plain origin now isolated from flooding by stream incisions; thickness 1 m to 10 m or more*

Af — *Alluvial fan sediments: gravel, sand, silt, and diamicton, poorly sorted; thick bedded to massive; sediments form fan-shaped landforms at the confluence of tributary streams with lower gradient trunk streams; subject to flooding accompanied by sudden stream migration and inundation by debris flows on fans with gradients in excess of 4%; thickness up to 10 m or more*

Au — *Alluvial sediments, undivided: sediments forming floodplains, fans, and terraces as above that cannot be subdivided at this map scale*

PLEISTOCENE AND HOLOCENE (UNDIVIDED)

EOLIAN DEPOSITS: well sorted medium sand to coarse silt transported and deposited by wind action during the early postglacial and McConnell Glaciation. Thin deposits of very fine sand and coarse silt < 1 m thick are distributed discontinuously throughout low lying areas (see SYMBOLS below)

Eb — *Eolian sands: sand, well sorted; massive; forms crescent-shape and linear dunes and featureless or gently undulating inter-dune eolian plains; thickness 1 to 5 m*

COLLUVIAL DEPOSITS: stony diamicton resulting from the physical and chemical breakdown of bedrock and reworking and transportation by creep, solifluction, debris flow, snow avalanching, and rockfall. It also includes diamicton created by landsliding. Colluvial deposits may contain reworked glacial sediments within the limits of ice cover during the Reid and McConnell glaciations. Colluvial deposits beyond the limits of the McConnell Glaciation ice cover are likely the product of continuous formation and reworking over a significant part of the Pleistocene

Cb — *Colluvial blanket sediments: diamicton, stony with a sandy matrix; massive; surface conforms to underlying bedrock or buried glacial deposits; thickness > 1 m to 50 m or more in large landslides*

Cv — *Colluvial veneer sediments: diamicton, stony with a sandy matrix; massive; thickness < 1 m to discontinuous over bedrock*

Ca — *Colluvial apron sediments: diamicton, bouldery diamicton and bouldery sandy gravel, poorly sorted; massive; sediments form a wedge-like slope-toe complex of small steep debris flow and avalanche-dominated fans and solifluction deposits; thickness is < 1 m at up and down slope limit to up to 5 m or more in the thickest part of the apron*

bCa — *Rockfall sediments: boulders, angular; massive; deposits form as rockfall accumulations along the bases of steep bedrock slopes; thickness ranges from < 1 m at margins to up to 10 m*

LATE PLEISTOCENE (WISCONSINAN) – McCONNELL GLACIATION

GLACIOLACUSTRINE DEPOSITS: well stratified sand, silt, clay, deposited in lakes ponded by glacial ice. Glaciolacustrine sediments may have regular surfaces or have ridged, hummocky, or pitted surfaces caused by meltout of former supporting glacial ice. Glaciolacustrine silt and clay commonly contain extensive segregated ground ice. Consequently, they are widely affected by thermokarst collapse and retrogressive thaw landsliding along rivers

Lp — *Glaciolacustrine plain: sand, silt, and clay with minor dropstones; thinly bedded to laminated; thickness > 5 m*

Lb — *Glaciolacustrine blanket: silt and clay with minor sand; thinly bedded to laminated; deposit conforms to underlying topography; thickness 1 m to 5 m*

Lv — *Glaciolacustrine veneer: silt and clay with minor sand; thinly bedded to laminated; deposit conforms to underlying topography; thickness < 1 m to discontinuous*

Lx — *Ice-contact glaciolacustrine complex: sand, silt, and clay; laminated to medium bedded with up to 10 percent lenticular beds of gravel and diamicton and dropstones; surface is hummocky, pitted, and ridged; thickness > 5 m*

GLACIOFLUVIAL DEPOSITS: sands, gravels and minor silts > 1 m thick deposited by streams flowing away from, or in contact with glacial ice including deltas graded to former glacial lakes. Sorting ranges from good to poor and stratification from thin bedded to massive. Sediments commonly display evidence of syndepositional collapse due to meltout of buried or supporting ice

Gp — *Glaciofluvial plain sediments: pebble to cobble gravel; massive to thick bedded, capped by sand and silt; planar surface; thickness 1 to > 10 m*

Gt — *Glaciofluvial terrace sediments: pebble to cobble gravel; massive to thick bedded; incised into flights of terraces by glacial streams; thickness 1 to > 10 m*

Gd — *Glaciofluvial delta sediments: sand, gravel, and minor silt and clay, moderately to well sorted, texture becomes finer downward; massive to thick bedded; deposit has a planar surface and delta-form in plan view; thickness > 5 m*

Gx — *Glaciofluvial ice stagnation complex sediments: gravel, sand, diamicton, poorly to moderately sorted, and minor silt and clay; bedding thick to massive and commonly folded and faulted from syndepositional ice meltout; surface consists of hummocks, kettles, esker and crevasse-fill ridges with minor elements of units* **Gp**, **Gd**, *and* **Gt**

Gu — *Discontinuous glaciofluvial sediments: gravel and sand including elements of units* **Gp** *and* **Gx**, *discontinuously distributed in areas of units* **Mb** *and* **Mv**

MORAINAL DEPOSITS (TILL): glacial diamicton, mainly till, generally consisting of a matrix ranging from sand to clay that supports clasts ranging from boulders to pebbles in size; deposited either directly from glacial ice or by gravity flow from glacial ice

Mb — *Till blanket: diamicton, stony with a silty, sandy matrix; massive to crudely stratified; surface conforms to the underlying topography; thickness 1 to 5 m*

Mv — *Till veneer: diamicton, stony with a silty, sandy matrix; massive to crudely stratified; may contain extensive areas of thin (< 1 m) to patchy colluvium over bedrock*

MIDDLE PLEISTOCENE – PRE-McCONNELL GLACIATION (UNDIVIDED)

ALLUVIAL DEPOSITS: gravel and sand deposited by streams that were not fed by glacial meltwaters. Sediments may represent several cycles of alluviation and erosion. Sediments are not presently correlative to past glaciations but presumably predate McConnell Glaciation due to the presence of McConnell age loess overlying them. Basal gravels within these sediments commonly contain placer gold in basins draining Cretaceous granodiorite and andesite

$A^{PM}f$ — *Alluvial fans: single fans or aprons of coalesced fans formed of gravel and sand, poorly to moderately sorted, thick bedded. Sediments disturbed by cryoturbation and clasts commonly wind sculpted. Thickness up to 10 m or more*

$A^{PM}x$ — *Alluvial complex sediments: gravel and sand, poorly to moderately sorted; thin to thick bedded, interstratified with colluvial diamicton, reworked loess, peat, and woody detritus; sediments underlie the floors and margins of narrow upland valleys and grade laterally (upslope) into colluvial blankets. They contain segregated ice lenses and ice wedges and are normally capped by blanket bog; sediments may represent several depositional cycles; thicknesses may exceed 10 m in mid-valley locations*

MIDDLE PLEISTOCENE – REID GLACIATION

ALLUVIAL DEPOSITS: complexes of nonglacial and fan sands and gravels deposited by streams that flowed from ice-free areas toward Reid Glaciation ice margins. These sands and gravels locally overlie older interglacial gravels that contain placer gold

$A^{R}t$ — *Alluvial terrace sediments: gravelly micaceous sand and gravel, moderately sorted, clasts angular to subangular; bedding is thin to massive and lenticular; gravel clasts are commonly frost shattered and wind sculpted. Sediments are commonly cut by ice wedge waters pseudomorphs over their upper 2 m (includes terrace gravels along Klaza River possibly deposited by outlet waters from a lake dammed by a glacial margin during Reid Glaciation). Thickness 1 to 15 m*

$A^{R}f$ — *Alluvial fans: single fans or aprons of coalesced fans formed of gravel and sand, poorly to moderately sorted, thick bedded. Sediments disturbed by cryoturbation and clasts commonly wind sculpted. Thickness up to 10 m or more*

$A^{R}x$ — *Alluvial complex sediments: gravel and sand, poorly to moderately sorted; thin to thick bedded, interstratified with colluvial diamicton, reworked loess, peat, and woody detritus; sediments underlie the floors and margins of narrow upland valleys and grade laterally (upslope) into colluvial blankets. They contain segregated ice lenses and ice wedges and are normally capped by blanket bog; sediments may represent several depositional cycles; thicknesses may exceed 10 m in mid-valley locations*

GLACIOLACUSTRINE DEPOSITS: well stratified sand, silt, clay, and minor gravel and diamicton deposited in lakes ponded by glacial ice. Glaciolacustrine silts and clays commonly contain segregated ground ice and are affected by contemporary thermokarst collapse

$L^{R}p$ — *Glaciolacustrine plain: sand, silt, and clay, with minor dropstones; thinly bedded to laminated; thickness 1 to > 5 m*

GLACIOFLUVIAL DEPOSITS: gravel and sand deposited by streams flowing away from, or in contact with glacial ice

$G^{R}p$ — *Glaciofluvial plain sediments: gravel and sand, moderately to well sorted; thick bedded to massive; planar surface; thickness 1 to 10 m or more*

$G^{R}t$ — *Glaciofluvial terrace sediments: pebble to cobble gravel; massive to thick bedded; incised into flights of terraces by glacial streams; thickness 1 to > 10 m*

$G^{R}d$ — *Glaciofluvial delta sediments: sand, gravel and minor silt and clay, moderately to well sorted and texture becomes finer downward; massive to thick bedded; planar surface, deposit a delta form in plan view; thickness > 5 m*

$G^{R}x$ — *Glaciofluvial ice stagnation complex sediments: gravel, sand, diamicton, poorly to moderately sorted, and minor silt and clay; bedding thick to massive and commonly folded and faulted from syndepositional ice meltout; surface consists of hummocks, kettles, esker and crevasse-fill ridges with minor elements of units* $G^{R}p$, $G^{R}d$, *and* $G^{R}t$

MORAINAL DEPOSITS (TILL): glacial diamicton, mainly till, generally consisting of a matrix ranging from sand to clay that supports clasts ranging from boulders to pebbles in size; deposited either directly from glacial ice or by gravity flow from glacial ice

$M^{R}b$ — *Till blanket: diamicton, stony, silty sandy matrix; massive; conforms to underlying topography; thickness 1 to 5 m*

$M^{R}v$ — *Till veneer: diamicton, stony, silty sandy matrix, massive; discontinuous and may contain extensive areas of thin (< 1 m) and patchy colluvium over bedrock*

EARLY PLEISTOCENE – YOUNGER PRE-REID GLACIATION

GLACIOFLUVIAL DEPOSITS: gravel and sand deposited by streams flowing away from glacial ice in meltwater channels and outwash plains. Thick bedded to massive, clasts, except for quartz, granite and chert are disaggregated or weathered to clay over the upper 2 m of the sediments where they underlie the surface; clasts near the surface of the unit are intensely wind sculpted and this interval is cut by ice wedge pseudomorphs and sand wedges; thickness 1 m to > 5 m

$G^{PR}p$ — *Glaciofluvial plain sediments: gravel and sand, deeply weathered; form an unincised plain*

$G^{PR}t$ — *Glaciofluvial terrace sediments: gravel and sand, deeply weathered; incised into flights of terraces*

MORAINAL DEPOSITS (TILL): glacial diamicton, mainly till, generally consisting of a matrix ranging from sand to clay that supports clasts ranging from boulders to pebbles in size; deposited either directly from glacial ice or by gravity flow from glacial ice

$M^{PR}v$ — *Till veneer: patchy, deeply weathered diamicton. Matrix sandy silty clay. Formerly feldspar-rich stones are weathered to clay*

EARLY PLEISTOCENE

VOLCANIC ROCK and INTERSTRATIFIED SEDIMENTS

V — *Pleistocene volcanics (undivided): basalt, breccia, volcanic ejecta and hyaloclastite of the Selkirk volcanics erupted during the early and late Pleistocene or early Holocene epochs in the Fort Selkirk area. Cumulative basalt flow thicknesses exceed 100 m where they have filled valleys. Deposits of the two known pre-Reid glaciations and at least one nonglacial period are locally interstratified with the volcanics and are exposed only in sections*

PALEOZOIC AND MESOZOIC

R — *PRE-QUATERNARY BEDROCK: basalt, andesite, greenstone, schist, gneiss, greywacke, granodiorite and monzonite; includes areas of thin colluvial cover, blockfields, sorted stone polygons in alpine areas*

R-A — *AVALANCHE MODIFIED PRE-QUATERNARY BEDROCK: bedrock areas subject to rapid mass wasting processes (rockfall and snow avalanches)*

SYMBOLS

Note: **pR** *- pre-Reid glaciations,* **r** *- Reid Glaciation,* **pM** *- pre-McConnell Glaciation, (no designator, assume McConnell Glaciation)*

- *Geological boundary*
- *Blanket bog covering generally less than 1 m thick*
- *Discontinuous eolian sands or silts, thickness locally up to 2 m*
- *Open system pingo, collapsed open system pingo*
- *Thermokarst collapse activity*
- *Landslide, arrow(s) indicate direction of movement*
- *Cirque: degraded cirque active prior to McConnell Glaciation*
- *Arête: degraded arête active prior to McConnell Glaciation*
- *Streamlined glacial bedforms: ice flow direction known, unknown*
- *Meltwater channel; large, small ice-walled channel, arrow indicates flow direction*
- *Esker: flow direction defined, unknown*
- *End moraine*
- *Recessional moraine*
- *Ice-contact face in stratified drift (teeth on ice side)*
- *Ice limit*
- *Cryoplanation terrace*
- *Tor*
- *Vertebrate fossil locality*
- *Stratigraphic section*

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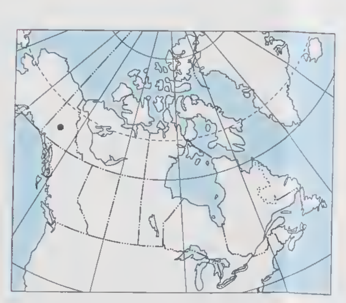
Published 1997



LOCATION MAP

MAP 1878A

SURFICIAL GEOLOGY

GRANITE CANYON

YUKON TERRITORY

Scale 1:100 000 - Échelle 1/100 000

Kilometres 2 0 2 4 6 8 Kilomètres

Universal Transverse Mercator Projection / Projection transverse de Mercator

Surficial geology by L.E. Jackson Jr. 1988-1992, Geological Survey of Canada

Digital cartography by J.D. Narraway, Geoscience Information Division

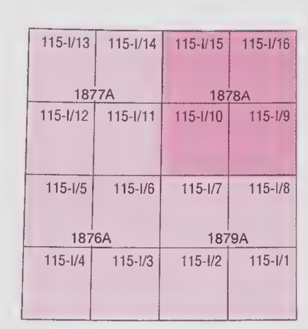
Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

Base map assembled and modified by the Geoscience Information Division from maps 115-I/10 (1984), 115-I/9 (1962), 115-I/15,16 (1961) published at the scale of 1:50 000 by the Surveys and Mapping Branch

Copies of the topographical editions covering this map area may be obtained from the Canada Map Office, Natural Resources Canada, Ottawa, Ontario, K1A 0E9

Mean magnetic declination 1997, 28°28' E, decreasing 12.1' annually. Readings vary from 28°11' E in the SW corner to 28°44' E in the NE corner of the map

Elevations in feet above mean sea level



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE AND INDEX TO ADJOINING GEOLOGICAL SURVEY OF CANADA MAPS

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Jackson, L.E., Jr.
1997: Surficial geology, Granite Canyon, Yukon Territory; Geological Survey of Canada, Map 1878A, scale 1:100 000

Canada

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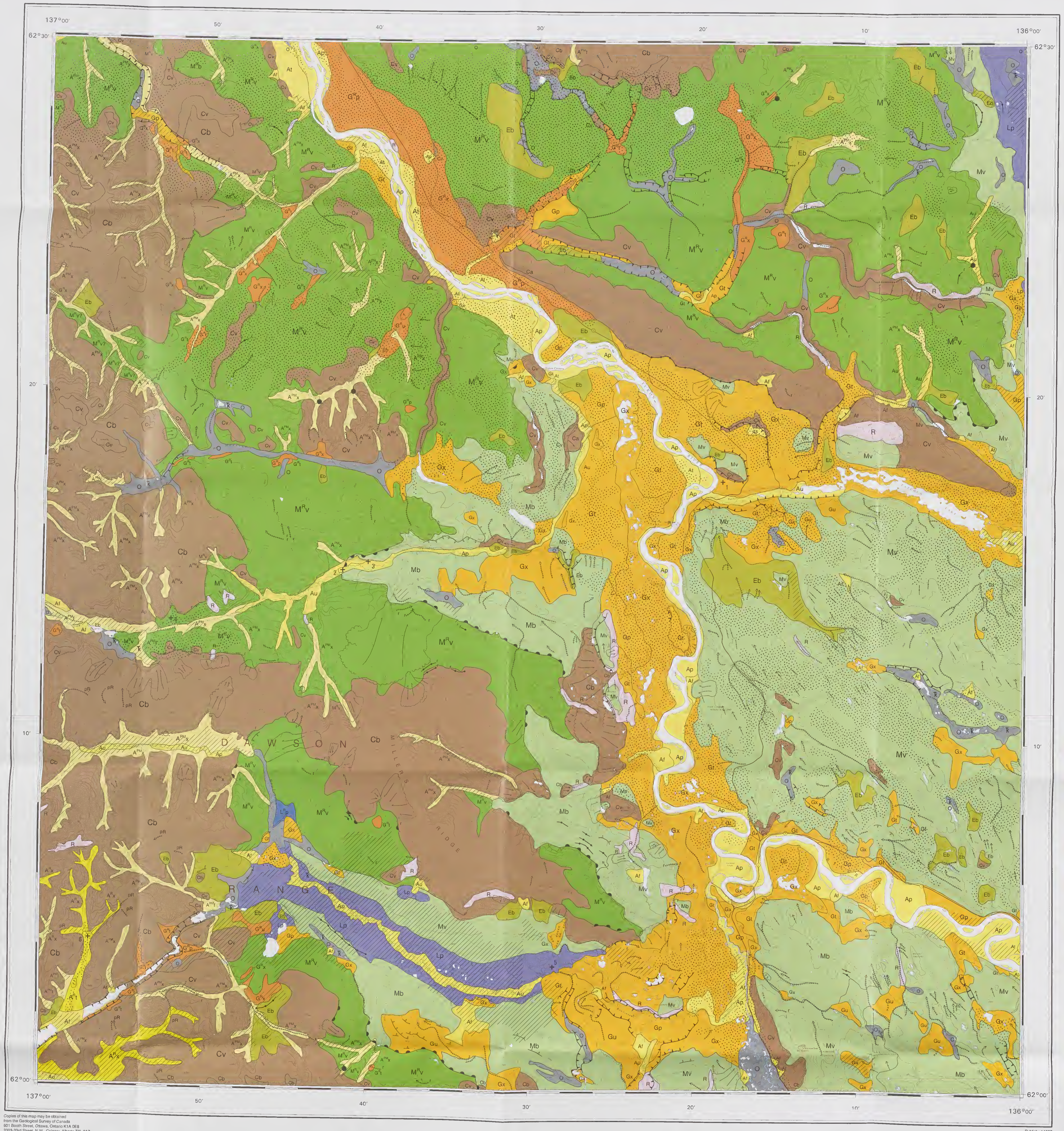

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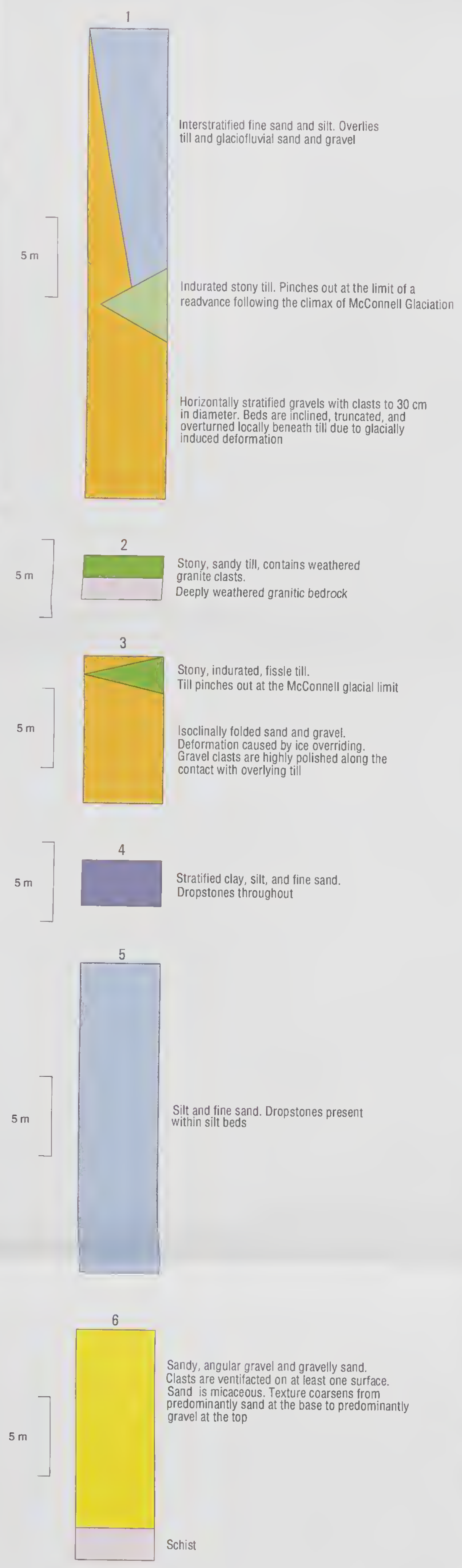


LEGEND FOR STRATIGRAPHIC SECTIONS

QUATERNARY

MIDDLE TO LATE PLEISTOCENE

- *Till, McConnell Glaciation*
- *Glaciolacustrine sediments, McConnell Glaciation*
- *Glaciofluvial sediments, McConnell Glaciation*

EARLY TO MIDDLE PLEISTOCENE

- *Till, Reid Glaciation*
- *Glaciolacustrine sediments, Reid Glaciation*
- *Alluvial sediments graded to the glacial margin, Reid Glaciation*

PRE-QUATERNARY

- *Paleozoic and Mesozoic bedrock*

LEGEND

Coloured legend blocks indicate map units that appear on this map
This legend is common to maps 1876A-1879A

CENOZOIC

QUATERNARY

HOLOCENE – POST-McCONNELL GLACIATION

ORGANIC DEPOSITS: *peat and muck formed predominently by the accumulation of vegetative material in bogs, fens, and swamps situated on valley bottoms and blanket bog on hillsides (see SYMBOLS below). Permafrost is commonly encountered within 1 m of the surface. Open system pingos are common in blanket bog and thermokarst collapse and palsa growth are common in bogs, fens, and swamps*

O — ***Bog, fen, and swamp deposits:*** *undivided; thickness < 1 m to 10 m*

ALLUVIAL DEPOSITS: *gravel to silt size sediments deposited by streams*

Ap — ***Floodplain sediments:*** *gravel, cobble to pebble; massive to thick bedded capped by sand and silt; flat lying; includes lacustrine and organic deposits in abandoned channels and backswamp areas subject to periodic inundation and reworking by floods; thickness 1 to 5 m*

At — ***Alluvial terrace sediments:*** *gravel, cobble to pebble with a sandy matrix; massive to thick bedded; capped by sands and silts; sediments are of flood plain origin now isolated from flooding by stream incisions; thickness 1 m to 10 m or more*

Af — ***Alluvial fan sediments:*** *gravel, sand, silt, and diamicton, poorly sorted; thick bedded to massive; sediments form fan-shaped landforms at the confluence of tributary streams with lower gradient trunk streams; subject to flooding accompanied by sudden stream migration and inundation by debris flows on fans with gradients in excess of 4%; thickness up to 10 m or more*

Au — ***Alluvial sediments, undivided:*** *sediments forming floodplains, fans, and terraces as above that cannot be subdivided at this map scale*

PLEISTOCENE AND HOLOCENE (UNDIVIDED)

EOLIAN DEPOSITS: *well sorted medium sand to coarse silt transported and deposited by wind action during the early postglacial and McConnell Glaciation. Thin deposits of very fine sand and coarse silt < 1 m thick are distributed discontinuously throughout low lying areas (see SYMBOLS below)*

Eb — ***Eolian sands:*** *sand, well sorted; massive; forms crescent-shape and linear dunes and featureless or gently undulating inter-dune eolian plains; thickness 1 to 5 m*

COLLUVIAL DEPOSITS: *stony diamicton resulting from the physical and chemical breakdown of bedrock and reworking and transportation by creep, solifluction, debris flow, snow avalanching, and rockfall. It also includes diamicton created by landsliding. Colluvial deposits may contain reworked glacial sediments within the limits of ice cover during the Reid and McConnell glaciations. Colluvial deposits beyond the limits of the McConnell Glaciation ice cover are likely the product of continuous formation and reworking over a significant part of the Pleistocene*

Cb — ***Colluvial blanket sediments:*** *diamicton, stony with a sandy matrix; massive; surface conforms to underlying bedrock or buried glacial deposits; thickness > 1 m to 50 m or more in large landslides*

Cv — ***Colluvial veneer sediments:*** *diamicton, stony with a sandy matrix; massive; thickness < 1 m to discontinuous over bedrock*

Ca — ***Colluvial apron sediments:*** *diamicton, bouldery diamicton and bouldery sandy gravel, poorly sorted; massive; sediments form a wedge-like slope-toe complex of small steep debris flow and avalanche-dominated fans and solifluction deposits; thickness is < 1 m at up and down slope limit to up to 5 m or more in the thickest part of the apron*

bCa — ***Rockfall sediments:*** *boulders, angular; massive; deposits form as rockfall accumulations along the bases of steep bedrock slopes; thickness ranges from < 1 m at margins to up to 10 m*

LATE PLEISTOCENE (WISCONSINAN) – McCONNELL GLACIATION

GLACIOLACUSTRINE DEPOSITS: *well stratified sand, silt, clay, deposited in lakes ponded by glacial ice. Glaciolacustrine sediments may have regular surfaces or have ridged, hummocky, or pitted surfaces caused by meltout of former supporting glacial ice. Glaciolacustrine silt and clay commonly contain extensive segregated ground ice. Consequently, they are widely affected by thermokarst collapse and retrogressive thaw landsliding along rivers*

Lp — ***Glaciolacustrine plain:*** *sand, silt, and clay with minor dropstones; thinly bedded to laminated; thickness > 5 m*

Lb — ***Glaciolacustrine blanket:*** *silt and clay with minor sand; thinly bedded to laminated; deposit conforms to underlying topography; thickness 1 m to 5 m*

Lv — ***Glaciolacustrine veneer:*** *silt and clay with minor sand; thinly bedded to laminated; deposit conforms to underlying topography; thickness < 1 m to discontinuous*

Lx — ***Ice-contact glaciolacustrine complex:*** *sand, silt, and clay; laminated to medium bedded with up to 10 percent lenticular beds of gravel and diamicton and dropstones; surface is hummocky, pitted, and ridged; thickness > 5 m*

GLACIOFLUVIAL DEPOSITS: *sands, gravels and minor silts > 1 m thick deposited by streams flowing away from, or in contact with glacial ice including deltas graded to former glacial lakes. Sorting ranges from good to poor and stratification from thin bedded to massive. Sediments commonly display evidence of syndepositional collapse due to meltout of buried or supporting ice*

Gp — ***Glaciofluvial plain sediments:*** *pebble to cobble gravel; massive to thick bedded, capped by sand and silt; planar surface; thickness 1 to > 10 m*

Gt — ***Glaciofluvial terrace sediments:*** *pebble to cobble gravel; massive to thick bedded; incised into flights of terraces by glacial streams; thickness 1 to > 10 m*

Gd — ***Glaciofluvial delta sediments:*** *sand, gravel, and minor silt and clay, moderately to well sorted, texture becomes finer downward; massive to thick bedded; deposit has a planar surface and delta-form in plan view; thickness > 5 m*

Gx — ***Glaciofluvial ice stagnation complex sediments:*** *gravel, sand, diamicton, poorly to moderately sorted, and minor silt and clay; bedding thick to massive and commonly folded and faulted from syndepositional ice meltout; surface consists of hummocks, kettles, esker and crevasse-fill ridges with minor elements of units* **Gp, Gd,** *and* **Gt**

Gu — ***Discontinuous glaciofluvial sediments:*** *gravel and sand including elements of units* **Gp** *and* **Gx**, *discontinuously distributed in areas of units* **Mb** *and* **Mv**

MORAINAL DEPOSITS (TILL): *glacial diamicton, mainly till, generally consisting of a matrix ranging from sand to clay that supports clasts ranging from boulders to pebbles in size; deposited either directly from glacial ice or by gravity flow from glacial ice*

Mb — ***Till blanket:*** *diamicton, stony with a silty, sandy matrix; massive to crudely stratified; surface conforms to the underlying topography; thickness 1 to 5 m*

Mv — ***Till veneer:*** *diamicton, stony with a silty, sandy matrix; massive to crudely stratified; may contain extensive areas of thin (< 1 m) to patchy colluvium over bedrock*

MIDDLE PLEISTOCENE – PRE-McCONNELL GLACIATION (UNDIVIDED)

ALLUVIAL DEPOSITS: *gravel and sand deposited by streams that were not fed by glacial meltwaters. Sediments may represent several cycles of alluviation and erosion. Sediments are not presently correlative to past glaciations but presumably predate McConnell Glaciation due to the presence of McConnell age loess overlying them. Basal gravels within these sediments commonly contain placer gold in basins draining Cretaceous granodiorite and andesite*

$A^{PM}f$ — ***Alluvial fans:*** *single fans or aprons of coalesced fans formed of gravel and sand, poorly to moderately sorted, thick bedded. Sediments disturbed by cryoturbation and clasts commonly wind sculpted. Thickness up to 10 m or more*

$A^{PM}x$ — ***Alluvial complex sediments:*** *gravel and sand, poorly to moderately sorted; thin to thick bedded, interstratified with colluvial diamicton, reworked loess, peat, and woody detritus; sediments underlie the floors and margins of narrow upland valleys and grade laterally (upslope) into colluvial blankets. They contain segregated ice lenses and ice wedges and are normally capped by blanket bog; sediments may represent several depositional cycles; thicknesses may exceed 10 m in mid-valley locations*

MIDDLE PLEISTOCENE – REID GLACIATION

ALLUVIAL DEPOSITS: *complexes of nonglacial and fan sands and gravels deposited by streams that flowed from ice-free areas toward Reid Glaciation ice margins. These sands and gravels locally overlie older interglacial gravels that contain placer gold*

$A^{R}t$ — ***Alluvial terrace sediments:*** *gravelly micaceous sand and gravel, moderately sorted, clasts angular to subangular; bedding is thin to massive and lenticular; gravel clasts are commonly frost shattered and wind sculpted; sediments have been incised into flights of terraces. Sediments are commonly cut by ice wedge waters pseudomorphs over their upper 2 m (includes terrace gravels along Klaza River possibly deposited by outlet waters from a lake dammed by a glacial margin during Reid Glaciation). Thickness 1 to 15 m*

$A^{R}f$ — ***Alluvial fans:*** *single fans or aprons of coalesced fans formed of gravel and sand, poorly to moderately sorted, thick bedded. Sediments disturbed by cryoturbation and clasts commonly wind sculpted. Thickness up to 10 m or more*

$A^{R}x$ — ***Alluvial complex sediments:*** *gravel and sand, poorly to moderately sorted; thin to thick bedded, interstratified with colluvial diamicton, reworked loess, peat, and woody detritus; sediments underlie the floors and margins of narrow upland valleys and grade laterally (upslope) into colluvial blankets. They contain segregated ice lenses and ice wedges and are normally capped by blanket bog; sediments may represent several depositional cycles; thicknesses may exceed 10 m in mid-valley locations*

GLACIOLACUSTRINE DEPOSITS: *well stratified sand, silt, clay, and minor gravel and diamicton deposited in lakes ponded by glacial ice. Glaciolacustrine silts and clays commonly contain segregated ground ice and are affected by contemporary thermokarst collapse*

$L^{R}p$ — ***Glaciolacustrine plain:*** *sand, silt, and clay, with minor dropstones; thinly bedded to laminated; thickness 1 to > 5 m*

GLACIOFLUVIAL DEPOSITS: *gravel and sand deposited by streams flowing away from, or in contact with glacial ice*

$G^{R}p$ — ***Glaciofluvial plain sediments:*** *gravel and sand, moderately to well sorted; thick bedded to massive; planar surface; thickness 1 to 10 m or more*

$G^{R}t$ — ***Glaciofluvial terrace sediments:*** *pebble to cobble gravel; massive to thick bedded; incised into flights of terraces by glacial streams; thickness 1 to > 10 m*

$G^{R}d$ — ***Glaciofluvial delta sediments:*** *sand, gravel and minor silt and clay, moderately to well sorted and becomes finer downward; massive to thick bedded; planar surface, deposit is delta form in plan view; thickness > 5 m*

$G^{R}x$ — ***Glaciofluvial ice stagnation complex sediments:*** *gravel, sand, diamicton, poorly to moderately sorted, and minor silt and clay; bedding thick to massive and commonly folded and faulted from syndepositional ice meltout; surface consists of hummocks, kettles, esker and crevasse-fill ridges with minor elements of units* **$G^{R}p$, $G^{R}d$,** *and* **$G^{R}t$**

MORAINAL DEPOSITS (TILL): *glacial diamicton, mainly till, generally consisting of a matrix ranging from sand to clay that supports clasts ranging from boulders to pebbles in size; deposited either directly from glacial ice or by gravity flow from glacial ice*

$M^{R}b$ — ***Till blanket:*** *diamicton, stony, silty sandy matrix; massive; conforms to underlying topography; thickness 1 to 5 m*

$M^{R}v$ — ***Till veneer:*** *diamicton, stony, silty sandy matrix; massive; discontinuous and may contain extensive areas of thin (< 1 m) and patchy colluvium over bedrock*

EARLY PLEISTOCENE – YOUNGER PRE-REID GLACIATION

GLACIOFLUVIAL DEPOSITS: *gravel and sand deposited by streams flowing away from glacial ice in meltwater channels and outwash planes. Thick bedded to massive; clasts, except for quartz, quartzite, and chert are disaggregated or weathered to clay over the upper 2 m of the sediments where they underlie the surface; clasts near the surface of the unit are intensely wind sculpted and this interval is cut by ice wedge pseudomorphs and sand wedges; thickness 1 m to > 5 m*

$G^{PR}p$ — ***Glaciofluvial plain sediments:*** *gravel and sand, deeply weathered; forms an unincised plain*

$G^{PR}t$ — ***Glaciofluvial terrace sediments:*** *gravel and sand, deeply weathered; incised into flights of terraces*

MORAINAL DEPOSITS (TILL): *glacial diamicton, mainly till, generally consisting of a matrix ranging from sand to clay that supports clasts ranging from boulders to pebbles in size; deposited either directly from glacial ice or by gravity flow from glacial ice*

$M^{PR}v$ — ***Till veneer:*** *patchy, deeply weathered diamicton. Matrix sandy silty clay. Formerly feldspar-rich stones are weathered to clay*

EARLY PLEISTOCENE

VOLCANIC ROCK and INTERSTRATIFIED SEDIMENTS

V — ***Pleistocene volcanics (undivided):*** *basalt, breccia, volcanic ejecta and hyaloclastite of the Selkirk volcanics erupted during the early and late Pleistocene or early Holocene epochs in the Fort Selkirk area. Cumulative basalt flow thicknesses exceed 100 m where they have filled valleys. Deposits of the two known pre-Reid glaciations and at least one nonglacial period are locally interstratified with the volcanics and are exposed only in sections*

PALEOZOIC AND MESOZOIC

R — ***PRE-QUATERNARY BEDROCK:*** *basalt, andesite, greenstone, schist, gneiss, greywacke, granodiorite and monzonite: includes areas of thin colluvial cover, blockfields, sorted stone polygons in alpine areas*

R-A — ***AVALANCHE MODIFIED PRE-QUATERNARY BEDROCK:*** *bedrock areas subject to rapid mass wasting processes (rockfall and snow avalanches)*

SYMBOLS

Note: **pR** *- pre-Reid glaciations,* **r** *- Reid Glaciation,* **pM** *- pre-McConnell Glaciation, (no designator, assume McConnell Glaciation)*

- *Geological boundary*
- *Blanket bog covering generally less than 1 m thick*
- *Discontinuous eolian sands or silts, thickness locally up to 2 m*
- *Open system pingo, collapsed open system pingo*
- *Thermokarst collapse activity*
- *Landslide, arrow(s) indicate direction of movement*
- *Cirque: degraded cirque active prior to McConnell Glaciation*
- *Arête: degraded arête active prior to McConnell Glaciation*
- *Streamlined glacial bedforms: ice flow direction known, unknown*
- *Meltwater channel; large, small ice-walled channel, arrow indicates flow direction*
- *Esker: flow direction defined, unknown*
- *End moraine*
- *Recessional moraine*
- *Ice-contact face in stratified drift (teeth on ice side)*
- *Ice limit*
- *Cryoplanation terrace*
- *Tor*
- *Vertebrate fossil locality*
- *Stratigraphic section*

MAP 1879A

SURFICIAL GEOLOGY

TANTALUS BUTTE

YUKON TERRITORY

Scale 1:100 000 - Échelle 1/100 000

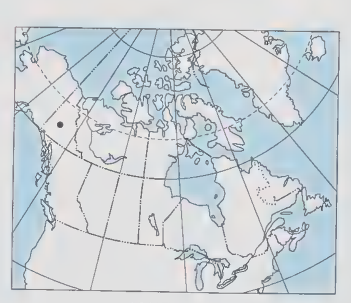
Kilometres 2 0 2 4 6 8 Kilomètres

Universal Transverse Mercator Projection / Projection transverse de Mercator

Surficial geology by L.E. Jackson Jr. 1988-1992, Geological Survey of Canada

Digital cartography by J.D. Narraway, Geoscience Information Division

Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada



LOCATION MAP

Base map assembled and modified by the Geoscience Information Division from maps 115-I/7 (1984), 115-I/2 (1969), 115-I/1 (1965), 115-I/8 (1961) published at the scale of 1:50 000 by the Surveys and Mapping Branch

Copies of the topographical editions covering this map area may be obtained from the Canada Map Office, Natural Resources Canada, Ottawa, Ontario, K1A OE9

Mean magnetic declination 1997, 28°06′ E, decreasing 11.9′ annually. Readings vary from 27°50′ E in the SW corner to 28°22′ E in the NE corner of the map

Elevations in feet above mean sea level

115-I/13	115-I/14	115-I/15	115-I/16
1877A		1878A	
115-I/12	115-I/11	115-I/10	115-I/9
115-I/5	115-I/6	115-I/7	115-I/8
1876A		1879A	
115-I/4	115-I/3	115-I/2	115-I/1

NATIONAL TOPOGRAPHIC SYSTEM REFERENCE AND INDEX TO ADJOINING GEOLOGICAL SURVEY OF CANADA MAPS

Recommended citation:
Jackson, L.E., Jr.
1997: Surficial geology, Tantalus Butte, Yukon Territory; Geological Survey of Canada, Map 1879A, scale 1:100 000

Canada

0'

Maps A–D are reconstructions of drainage systems, glacial ice limits, and geomorphic features drawn on a shaded relief digital elevation model at a scale of 1:750 000.

Map A Speculative preglacial drainage

Prior to glaciation (Map A), Yukon River flowed to the south at a level of at least 120 m above its contemporary bed. It may have alternated between channels A and B (the contemporary valleys of Yukon and Nordenskiold rivers, respectively) in the area of Carmacks. In the southwest, the drainage now tributary to Klaza River followed the valley of Lonely Creek southeastward. A low stream divide (C) was breached presumably during the subsequent pre-Reid glaciations. In the northwest, the deep, narrow canyon of the contemporary Yukon River was occupied by a stream divide separating the preglacial Yukon River basin from the preglacial Stewart River basin (D). This was also breached during the subsequent pre-Reid glaciations. Along the northern boundary of Carmacks map area, terrain now drained by Grand Valley and Lava creeks (Map B) into the Stewart River basin, flowed south. Drainage divide E prevented northwestward flow. Drainage in the northeast was dominated by preglacial Willow Creek. The segment of Pelly River between Fort Selkirk and Willow Creek was occupied by drainage divide F. East of preglacial Willow Creek, Pelly River and Needlerock Creek may have been local, minor streams. Divide G formed part of the headwaters of preglacial Pelly River. The main flow from what is now Pelly River basin may have followed a southwestern course east of the Carmacks map area.

Map B Pre-Reid glaciations

The last of at least two pre-Reid glaciations ended more than three-quarters of a million years ago. Erosion and colluviation have eroded or buried most of the deposits of these glaciations beyond the limit of ice cover during the subsequent Reid and McConnell glaciations (which removed all evidence of older glaciations). Eroded cirque-like features in Dawson Range and till deposits of entirely local provenance in this area indicate that cirque glaciers or ice caps existed there during the pre-Reid events. Elsewhere, glacier ice from the east and southeast generally flowed west-northwest across the area. Probably only scattered peaks in Dawson Range escaped glaciation. The reversal of Yukon River drainage and its diversion west into Stewart River basin were glacially induced. Breaching of stream divides in the Klaza and Lava-Grand Valley creek basins also occurred. The cutting of the valley of Pelly River between Fort Selkirk and Willow Creek and the breaching of drainage divide G (Map A) created a Pelly River course similar to the contemporary one. In the area of P, the course initially ran from P to R. Granite Canyon (G–G'), the contemporary course, was cut by glacial diversion of Pelly River either during the Reid or McConnell glaciations. It is not possible to determine when other cross-upland glaciofluvial drainage system such as U (northeast of Carmacks) were initally cut. The last pre-Reid glaciation was accompanied by extensive fissure eruptions of basalt in the Fort Selkirk area and the subglacial eruption of Ne Ch'e Ddhäwa volcanic edifice (V).

00'

Map C Reid Glaciation

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Natural Resources Canada · Ressources naturelles Canada

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Map C Reid Glaciation

The Cordilleran Ice Sheet, more accurately described as a complex of valley glaciers, generally flowed from southeast to northwest across the Carmacks area. Flow was controlled by the direction of major valleys. The highest hills east of the Yukon River stood above the ice sheet as nunataks. It pressed against the Dawson Range along its eastern margin. Ice crossed the Dawson Range at Seymour Creek (S),an unnamed creek (U), and at the headwaters of Nisling River (N). It also pushed up Big Creek to B. Evidence exists to suggest that it also dammed a lake south of Carmacks map area which flooded the Lonely Creek valley (L). The lake spilled across the divide into Klaza River drainage (K). Subsequent erosionand colluviation and deposition of loess during McConnell Glaciation make determination of the limitsof glacial ice during Reid Glaciation difficult. Limits are queried (?) in many places as a result.

Map D McConnell Glaciation

Ice cover was restricted to the eastern margin of Carmacks map area during McConnell Glaciation. As in Reid Glaciation, the Cordilleran Ice Sheet could better be described as a complex of coalescent valley glaciers. Glacier flow directions were entirely dictated by the major valleys. Glaciers in the Pelly River and Needlerock Creek valleys (A and B) were termini of the Selwyn Lobe of the Cordilleran Ice Sheet whereas the Mica Creek (C) and Yukon River valley (D) glaciers were termini of the Cassiar Lobe (see Fig. 5).

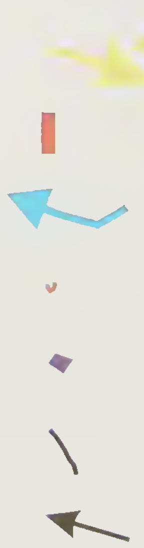
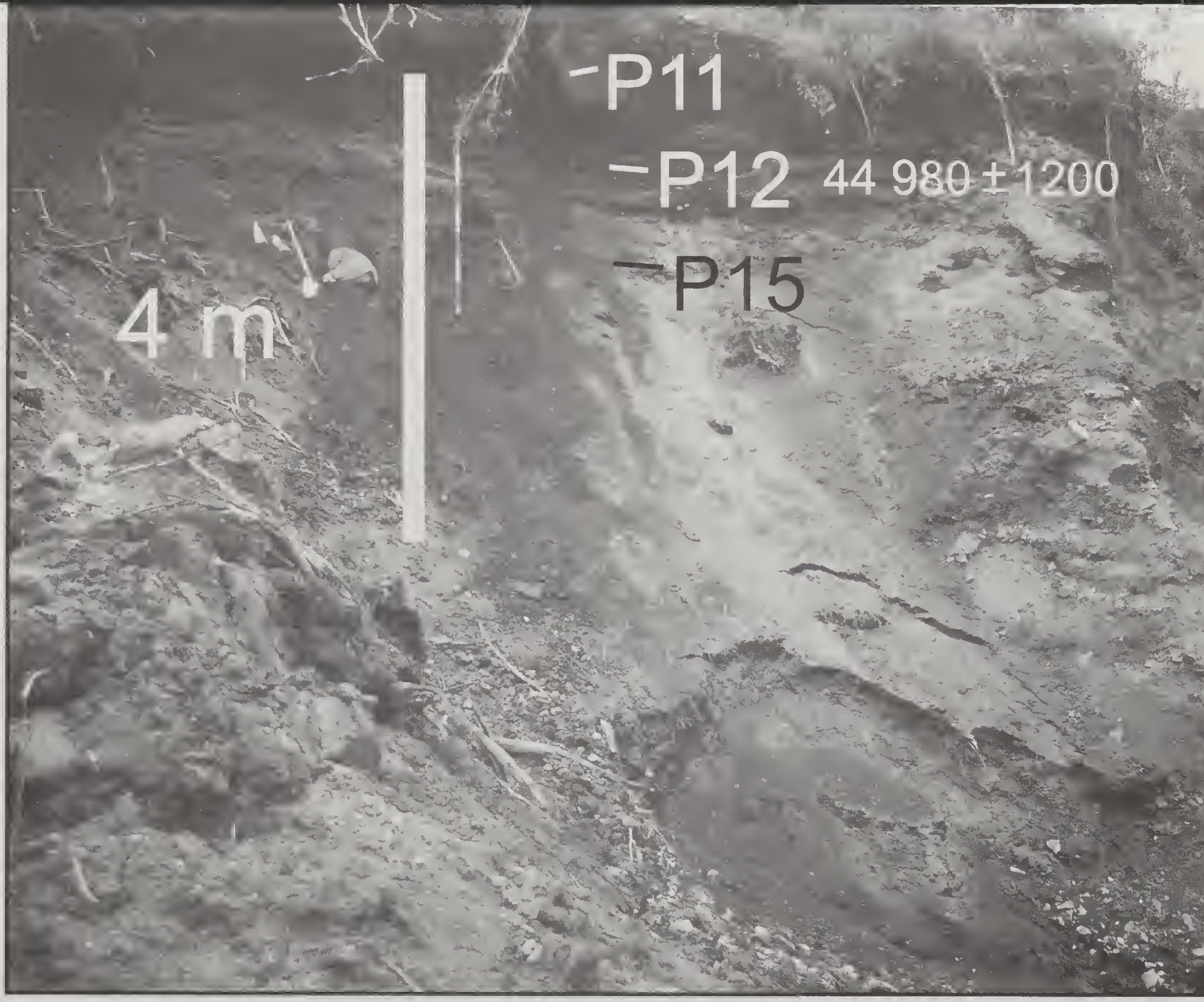


Figure 3. Preglacial drainage and ice limits.



e) Sample locations and radiocarbon ages at upstream section. Photograph by L.E. Jackson, Jr. GSC 1999-012K

FIGURE 28

EXHIBIT F - 1

ROUTE 3 RELOCATION ALTERNATIVE NO. 1

VICINITY MAP

LEGEND

PROPOSED ROUTE 3
EXISTING ROUTE 3
RAILROAD CORRIDOR
NEW YARD R.O.W.
ROUTE 3 R.O.W.
67dBA Leq (1hour) MAX.

400 200 0 400

SCALE IN FEET

ST. LOUIS MARGE PROJECT
SVERDRUP / ENVIRODYNE / KNIGHT